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ELK SEASONAL RANGES AND MIGRATION

A Final Report

RICHARD L. BROWN

September 1990

FEDERAL AID IN WILDLIFE
RESTORATION PROJECT

Arizona Game and Fish Department Mission

To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft recreation for the enjoyment, appreciation, and use of present and future generations.

Arizona Game and Fish Department
Research Branch

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Elk Seasonal Ranges and Migrations

Richard L. Brown

Abstract: From 1985 to 1989, 105 (3 male, 102 female) Arizona elk (*Cervus elaphus nelsoni*) were radio tracked from aircraft at approximately 30-day intervals. Mapped locations tended to form discrete clusters that identified seasonal use areas. The telemetered elk showed a high degree of fidelity to these seasonal use areas. Subsequently, a population of elk that used each use area was defined, and the level of exchange with other use areas was determined. Thus, migration patterns between use areas and, consequently, herd boundaries were determined. Time and duration of migration periods were documented also. The implications of managing on a herd unit basis are discussed.

INTRODUCTION

Arizona elk *(Cervus elaphus nelsoni)* hunt management strategy is based on a limited number of elk permits being allocated annually to each of several game management units (GMU) (Figure 1). Hunting seasons are a mixture of general firearms, archery only, and muzzleloader hunts with different starting and ending dates. Because Arizona elk are migratory and frequently cross GMU boundaries, a thorough understanding of their movement patterns is necessary if limited quota hunting within individual management units is to work as intended. If two adjacent units are hunted during different date frames and a migration occurs during the interim period, a herd could inadvertently be subjected to two hunts. A closely related problem concerns the proper application of elk survey data. In some cases, elk may be surveyed in one GMU and hunted in another; therefore, the survey results may not be accurately reflecting the number of elk available in any given unit. Detailed seasonal use data would enable managers to deal with this problem as well. Recently, there has been a considerable amount of discussion on the feasibility of managing Arizona's elk on the basis of herd units as opposed to arbitrarily defined management units.

The grouping of individual animals can be related to a variety of causes that includes feeding, migration, reproduction, and increased defense against predation (Whittenberger 1981). Although groupings of ungulates are frequently referred to as herds, there appears to be no formal definition of the term. The use of "herd" in current literature is so generalized that it denotes almost any assemblage of large animals and can imply either a social cohesiveness, an attachment of individuals to specific geographic areas, or both. Reports by several authors (Brazda 1953, Anderson 1958, Picton 1960, Tanner 1965, Knight 1970, Craighead et al. 1972, and Waldrip and Shaw 1979) indicate that elk tend to return to the same seasonal ranges year after year. Information obtained from an earlier visibility collar study conducted by the Arizona Game and Fish Department is in agreement (Elk Investigations, W-53-R Performance Reports in Arizona Big Game Investigations, Wildlife Management Division, Arizona Game and Fish Dept., volumes 1974–75 through 1982–83).

Several studies have suggested that there is a high rate of exchange of individuals among groups on seasonal ranges (Harper 1964, Franklin et al. 1975, Struhsaker 1967:81 in Shoesmith 1979). Shoesmith (1979) drew the following conclusions from a Montana study. The only recognizable social unit is the family unit that is limited to the cow, her calf, and possibly her yearling offspring. There was a high rate of exchange for both family units and individuals among groups on summer and winter range. Likewise, migrations to and from seasonal home ranges did not occur "en masse" by "organized" groups. However, there was evidence of repeated or habitual use of seasonal ranges by the study animals. Thus, herd integrity may best be addressed by an examination of the degree that elk return to a geographic location over time. It is this "geographical" aspect of herd integrity upon which the current Arizona management options are dependent. For our purposes then,

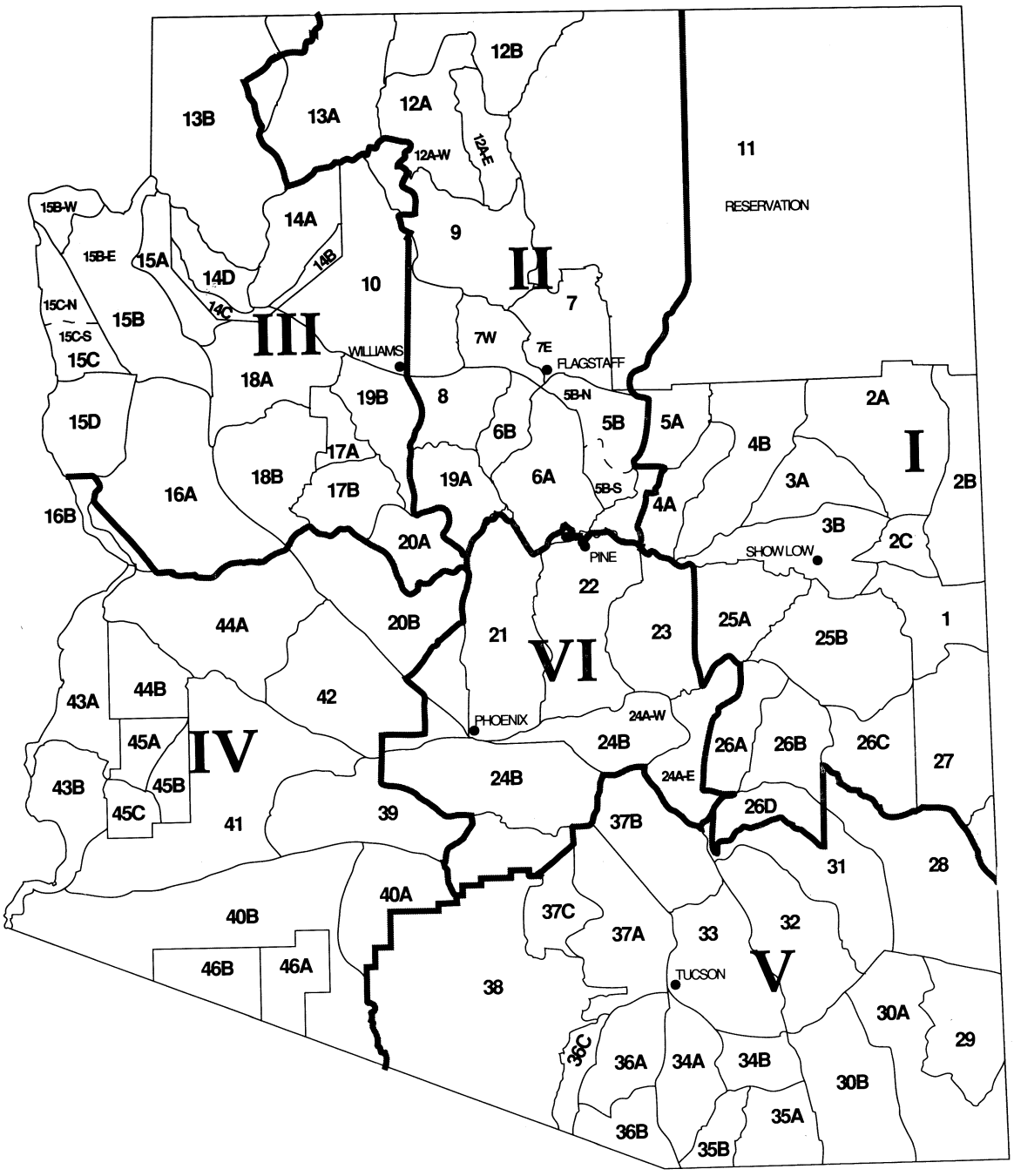

Figure 1. Arizona Game and Fish Department Game Management Units (GMU) and Administrative Regions.

the degree of "fidelity to seasonal use areas" is a more important criterion than degree of social cohesiveness, and the issue needs only to be approached from that standpoint.

In 1974 an investigation was initiated under Federal Aid Project W-53-R Work Plan 3, Job 1 to determine the discreteness of elk herds along the Mogollon Rim. In Arizona Game and Fish Department's Region I (Figure 1), 380 colored visibility collars were installed. In Region II (Figure 1), 343 visibility collars and 27 radio collars were installed. Combined, these collars have resulted in over 700 repeat observations (sightings, recaptures, and hunter returns) and over 300 radio locations. This study evolved out of those initial efforts, and the objectives are listed as follows:

- Identify areas of seasonal use and describe the fidelity of elk to those areas.
- Determine the timing and regularity of elk migrations.
- Identify boundaries of discrete elk herds, if present, and describe the degree of herd integrity.
- Determine whether herd units cross current game management unit boundaries.

STUDY AREA

The radio telemetered animals involved in this study ranged from the Tusayan area on the south rim of the Grand Canyon, south to Williams, Arizona, then east along the Mogollon Rim to the Arizona/New Mexico border (Figure 2). This area encompassed an elevational range of approximately 1500–2850 m, composed primarily of Ponderosa pine *(Pinus ponderosa)* and mixed conifer forests (Pase and Brown 1982:43) at higher elevations, and piñon/juniper (*Pinus edulis / Juniperus spp.*) woodland (Brown 1982:52) at lower elevations.

METHODS

Capture and Telemetry

Elk were captured in portable box traps (Clover 1956) during both summer and winter periods (Figure 2). Between January 1985 and June 1989, 105 mortality sensing radio transmitters (manufactured by Telonics, Mesa, Arizona) were placed on 3 male and 102 female elk in 11 GMUs. Capture site selections were chosen primarily on the recommendations of Wildlife Managers and Regional Game Specialists. Attempts were made to sample all major elk concentrations within any GMU with a maximum of five collars being installed per trap site. Elk were located at 1–month intervals except during primary migration periods (late November–early December, and late March–early April) when locations were made every other week. Three thousand and ninety-two locations were obtained from fixed wing aircraft equipped with twin 3-element yagi antennas mounted on the wing struts and a single rotary H-type antenna mounted on the belly of the plane. Observations were recorded on 71/2–minute U.S.G.S. topographic quadrangles, with a locational accuracy of within 400 m considered acceptable.

Determination of Seasonal Use Areas

Haywood et al. (1987) described the results of an extensive radio tracking study involving North Kaibab mule deer. These animals moved to the periphery of their high elevation summer range in late summer where they remained until weather or some other factor induced them to move to lower elevation winter range. Return migrations were not made until the following spring. Seasonal use areas, defined by least-sided convex polygons, therefore could be easily related to altitudinal ranges and calendar date frames. Elk involved in the current study did not exhibit this consistency. Weather patterns usually initiated the migration to winter range. However, a reversal of that pattern frequently resulted in a return migration to summer range, even during early winter. This pattern reverse would have produced very broad home range polygons encompassing all altitudinal ranges used during the year. Any attempt to define seasonal use areas solely on the basis of date frames would have produced similar results. It also appeared that the use of centroids from individual home range polygons would have been inadequate because of the large number

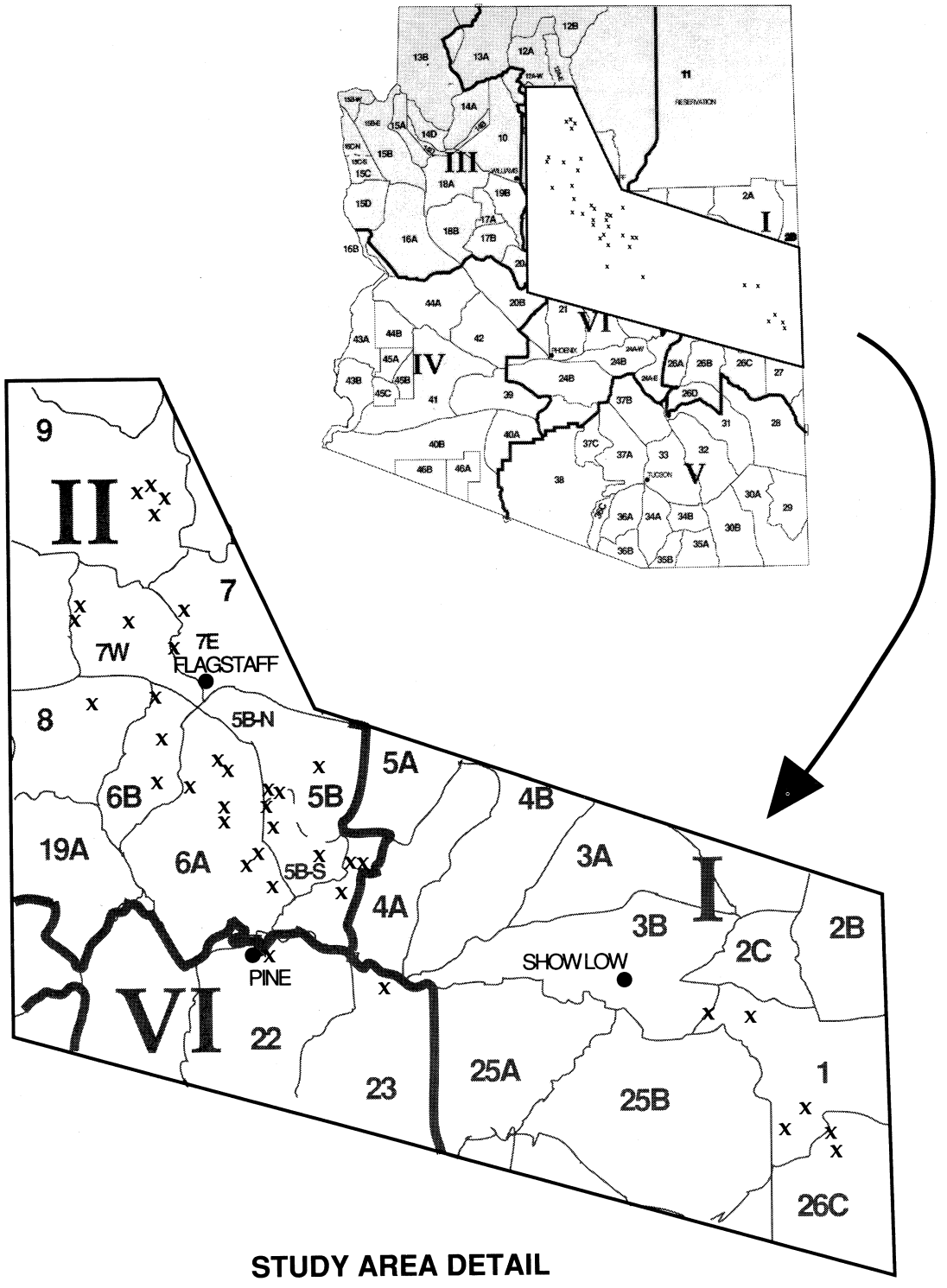

Figure 2. Study area boundary and location of elk trap sites.

of GMU boundaries involved. Additionally, a method that would readily yield information on levels of population exchange between areas was needed; therefore, a different approach was selected.

The 3092 elk locations from all animals across all years were plotted with a geographical information system. Contours were subjectively drawn around all discrete clusters of elk locations. Knowledge of regional elk behavior and topography, gained during the radio tracking phase of the study, was used to assist in defining boundaries between adjacent clusters. Also, similar seasonal maps were constructed for the periods of January–March (winter) and June–August (summer). Preliminary analysis of telemetered elk movements indicated that relatively little migratory activity would be encountered at those times. Therefore, observations would tend to fall almost entirely into either summer or winter use areas. These seasonal maps were used as guidelines for dividing nondiscrete clusters (those known to encompass both summer and winter use areas) into two or more separate clusters. The boundary around a cluster of observations defined a use area. Each use area was then assigned an identification number for further analysis.

At the outset of this study, the W-53-R visibility collar study results through mid 1983 were reviewed, and information from that study was used periodically for comparative purposes in this report.

Seasonal Use Area Fidelity

Use areas were classified as either winter or summer ranges based on the relative number of locations observed in January through March as compared with June through August, respectively. This decision was based on preliminary data analysis, which indicated that most, if not all, elk would be found on their respective winter and summer ranges and that few elk would move to or from those ranges. An arbitrary decision rule was used, so that 67% or more of the observations was required to occur in a certain category before that use area was classified accordingly. In some cases, "all season ranges" were identified when seasonal use was relatively equal.

Fidelity of elk to a particular use area was evaluated by the degree that elk remained within that use area boundary during the appropriate season. If an elk was located within a use area boundary, then the frequency that the same individual was located in any other use area was counted and those areas noted. For example, consider that six specific elk were located in Use Area 7 during June through August across all years. During that period they were located 58 times, but only 44 of those 58 locations occurred within the confines of Use Area 7. The remainder of the locations occurred in two other use areas.

Consequently, those elk located at least once within a use area boundary, considering all observations, were viewed as a subpopulation for comparison purposes. The movements of those elk were then examined during the use area's respective season only. The total number of either winter or summer observations of this subpopulation was counted, and the percentage of those observations that occurred within the seasonal use area boundary was calculated. The seasonal use area fidelity index then is defined as the proportion of all seasonal locations (of individual elk that ever occupied that use area) that occurred within that use area boundary. If most of the elk that ever occupied a seasonal use area rarely left that area during the season, then the index would approach a value of 1.00. Thus, the percentage value estimates the degree of fidelity to a seasonal use area, during the season of primary use, for the subpopulation of elk using each area.

The fidelity index was calculated for each use area, using the appropriate time period depending on the area's seasonal classification. The denominator was the total number of locations of a subpopulation during each period. The numerator was the number of those locations that occurred within the designated use area. Following initial calculations, some areas were combined or boundaries redrawn to improve index values.

Additionally, fidelity index values for June through August were compared with those of

late August and September. During late August and early September, one of the two annual elk classification counts is conducted to determine the prehunt bull-to-cow ratio data for the year. This comparison, then, questions the validity of applying elk distribution data, as reflected in the June–August fidelity ratings, to the late August and September period. Some hunting, as well as most of the rutting season, also occurs during September.

Migration Patterns

Migration patterns were determined by examining which winter use areas were occupied by elk from a given summer range, and vice versa. Given the subpopulation of all individuals that occupied a certain summer use area, each winter use area that was occupied by those same individuals was identified, and the percentage of locations occurring within each of those winter use areas was calculated. The result indicates what winter use areas a summer subpopulation used and roughly estimates the percent of time spent in each. Viewed collectively, the index values indicate where and in what proportions all elk that used an area came from or went to within a season or among seasons.

Timing of migration was determined by examining the proportion of elk migrating to or from each use area during each month of migration. Individuals were considered to have either "left" or "entered" an area when they remained in that particular category for the rest of the season. If, for example, an animal left Area 16 in March, entered Area 19 in April, returned to Area 16 in May and re-entered Area 19 in June to stay through October, then it was considered as having left Area 16 in May and entered Area 19 in June.

Exchange between GMUs was determined in the same manner as that discussed above. Given the subpopulation of all elk occupying a GMU, other units occupied by those elk were identified, and the percent of time spent in each (based on number of sightings) was computed. Calculations were based on use across the entire year rather than two 3-month periods.

Herd Units

Herd units were defined by combining use areas containing the largest number of common elk. Only the "across season" migration data were used (i.e., for summer use areas the January–March percentages were used and vice versa). The objective was to produce a block of use areas with the highest possible percentage of self-containment of across season observations. Such a block frequently contained several summer and winter use areas.

RESULTS

Seasonal Use Area Fidelity

Elk locations tended to group into clusters from Williams, east to Woods Canyon Lake (45 km east of Pine, Arizona), and 35 individual use areas were identified (Appendix 1, Figure 3). Twenty-four more were identified just south of Showlow (Figure 4). These individual use areas separated into 25 summer, 26 winter, and 8 all season use areas. The number of elk that was observed within each seasonal use area and that comprised that area's subpopulation is given in Appendix 2. These values were listed separately to avoid confusion with the "working n-values" (number of locations), listed in most of the other tables.

From one to six individual use areas were used by an individual area's subpopulation of elk during any given season (Appendix 3–7). In several instances, individual fidelity values were relatively low. However, when closely associated use areas were combined, relatively high fidelity ratings were obtained, and the combination was considered one use area.

Consider for example Use Area 1 (Appendix 3). All of the telemetered elk that were ever observed in Area 1 during the entire study were located there 36 times during June through August. Twenty-one of those 36 observations (58%) occurred in Area 1. This does not suggest a particularly high level of fidelity to that area and obviously is due to the high level of involvement by these same elk with Area 3 (36%). These values suggest that the elk that occupied Use Area 1, at any time

during the summer months, spent only 58% of the 3-month period in that area, approximately 36% in Area 3, and the remaining 6% was spent in Area 2, which was classified as winter range.

The foregoing also indicates that combining Areas 1 and 3 into a single area might be appropriate. Area 3 did not attain the 67% level and therefore was classified as an all season use area (Appendix 1), although it tended to be used more heavily in summer than winter. By combining Areas 1 and 3 on the basis of summer use (Appendix 6), the fidelity rating increased to 91%. However, because the combination of Areas 1 and 3 qualifies as an all season (as opposed to summer) use area, percentage calculations should be based on winter and summer observations combined (Appendix 5). This is still an improvement, with 78% of the total summertime expenditure by animals that used Areas 1 and 3 at any time during the January–March and June–August periods (for all practical purposes, year round) occurring in Areas 1 and 3 combined. Seventeen percent of the summertime expenditure was in Area 2, 1% in Area 5, and 4% in Area 8.

The mean value for seasonal use area fidelity (Appendix 3, 4, and 5, using combined values 1 and 3, 6 and 7, etc.) was 72%. The mean fidelity value for the GMUs was 47–57% if use areas where no capture work was done were excluded (Appendix 8).

Fidelity ratings (Appendixes 3 and 7) changed very little when September observations were included with the June–August data (Appendix 9). Addition of the September data increased the mean fidelity ratings for summer and all season use areas 0.7% and 0.3%, respectively. Only one individual use area rating changed more than 4%.

For summer use areas, the mean of September values by themselves was approximately 7% lower than the mean value for the June–August period. This difference is not considered to be important because the 7% value was an average for the entire month of September, and the elk surveys were conducted in late August and early September. June–August fidelity values should therefore be applicable to this survey period. The October value, however, declined about 14%. This decline is the beginning of an annual downward trend as individuals begin to migrate to winter range, but both the June–August and June–September values appear to reflect the same geographical distribution of elk.

Migration Patterns

Generally, elk movements were restricted between a limited number of seasonal use areas, and elk habitually used the same summer and winter ranges (Appendixes 10–14). In many cases, elk that occupied two separate winter use areas shared the same summer use area, and vice versa. For example, consider Use Area 6 (Appendix 10). All elk that ever occupied Summer Use Area 6 were located 37 times during winter (January through March). Twenty–eight of these (76%) occurred in Use Area 4. Likewise, of all elk that ever used Winter Use Area 4, 40% of their summer observations occurred in Summer Use Area 6 and 32% occurred in Area 9, which is adjacent to Area 6 (Appendix 11).

It was fairly common for a use area that elk were "migrating from" to be counted also as a destination, despite the narrow 3-month date frames used in the tabulations (e.g., Area 34, Appendix 10). This calculation is the result of either incomplete (not all elk) migrations because of mild winters or short-lived reverse migrations that are due to temporary weather reversals. Consequently, the reader may wish to exclude these calculations from consideration for any particular use area. If, for example, the 7 winter observations that occurred in Summer Use Area 34 were excluded (Appendix 10), then there would have been only 41 total winter observations, 100% of which occurred in Area 33.

In general, the months most frequently used for spring and fall migrations were March, April, May, (Appendix 15) and October, November, December, respectively (Appendix 16). A considerable amount of movement was apparent throughout December, extending into January, and times of migration did vary somewhat from use area to

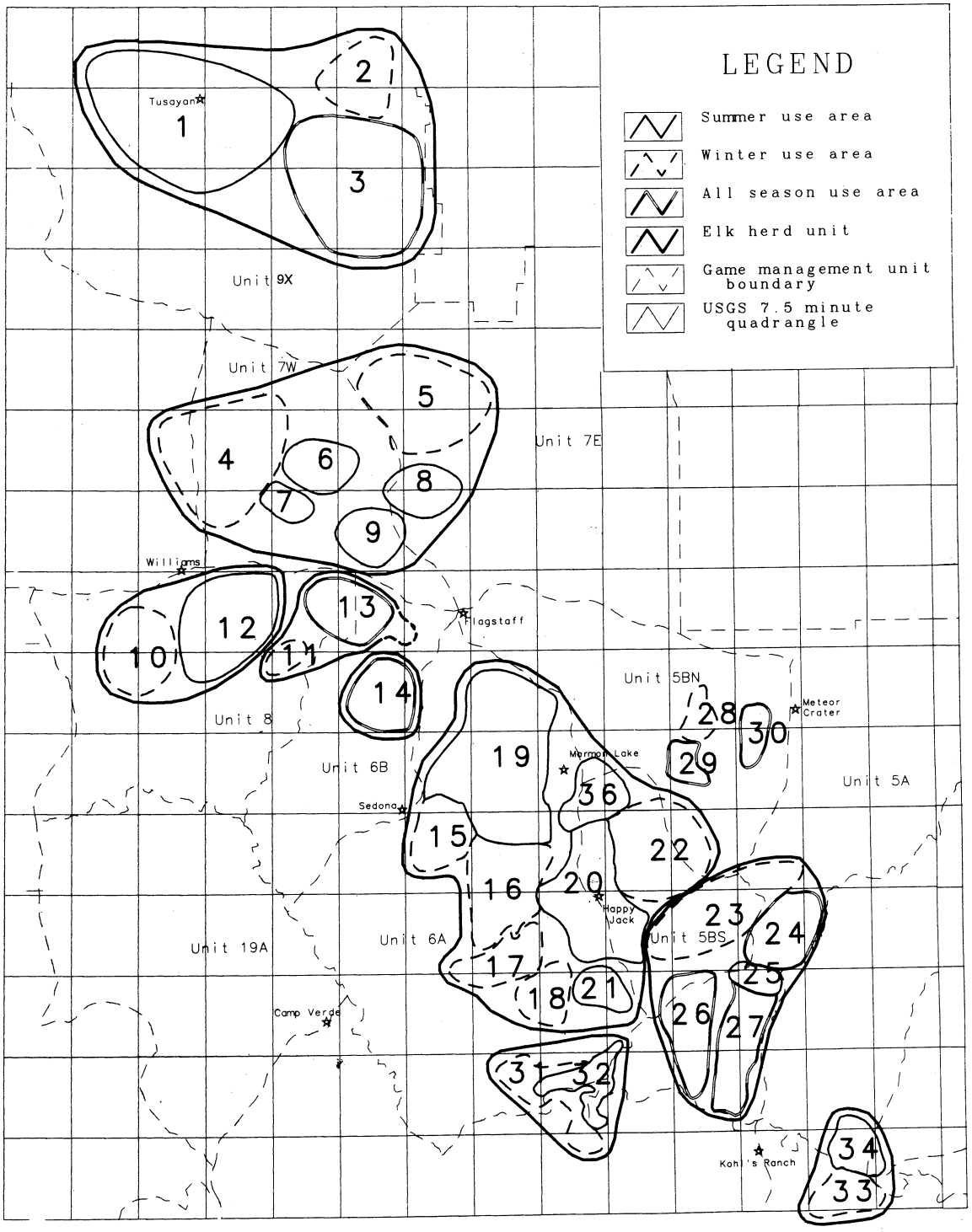

Figure 3. Seasonal use areas and herd unit boundaries of elk occurring within Region II.

use area (Appendixes 17, 18, and 19). Most individuals were radio tracked over a 2-1/2 year period. In one sense then, these tables present extremes obtained across years. Values span the time from when the earliest migrating animal entered an area to remain for the season, during the year of earliest migration, through the time when the latest migrating animal left, during the latest year of migration.

During the months of migration, both summer and winter ranges were used jointly (Appendix 20). Migration between seasonal use areas typically occurred over several weeks with more herd members continually arriving. Elk also were observed to reverse their movements (most often in the fall), return to their origin, and move alternately between seasonal ranges. Furthermore, migration starting dates varied over the years of study. When considered across all years, the first and last month of migration (spring or fall) define a period of joint use. For example, in Area 11 (Appendix 20), 67% of the use area's subpopulation was jointly using both summer and winter range during October–December, and a separate 33% was doing the same in November–December.

Elevations of elk locations on winter use areas ranged from a low of 1701 m to a high value of 2782 m and ranged from 1876—2929 m on summer use areas (Appendix 21). The observations from Areas 28, 29, and 30 were excluded because of small sample size. The summer low of 1876 m and winter high of 2782 m demonstrate a large degree of overlap. Elevations of elk locations on all season use areas overlapped elevations of elk locations on both winter and summer range (1939—2530 m, Appendix 21).

Considering all locations, it was impossible to separate summer from winter range on the basis of elevation. However, a Scheffe multiple range test showed that in most cases there were significant differences between summer and winter use areas ($P < 0.10$) when comparisons were confined within the herd units outlined in Figures 3 and 4. Excluding Use Areas 28, 29, 30, and the all season use areas, 66 winter to summer use area comparisons were made within individual herd unit boundaries. Only 12 of these use areas did not exhibit a significant difference in elevation mean: 2 and 1; 10 and 12; 22 and 20; 22 and 36; 18 and 21; 23 and 25; 37 and 43; and 44, with 43, 45, 46, 47, and 48. In these cases, differences in vegetation type, thermal cover, or seasonal food supplies may be evident, but elevational range alone could not be used to differentiate between those summer and winter use areas.

Herd Units

Twelve discrete elk herds were delineated through examination of seasonal use areas that were shared by common elk (Figures 3 and 4). The boundaries of each herd were determined by drawing a contour around seasonal use areas that were related by migration patterns. Two known groups of elk were not studied because trapping efforts failed to capture any elk from either group. The first group inhabits the Rogers Lake area just north of Use Area 14. The second occupies Anderson Mesa north of Use Area 36. While some telemetered elk were observed to move between the herd boundaries, herd fidelity was very high. Following is a description of each herd, its degree of fidelity, and the interrelationships of its internal use areas.

Areas 1, 2, 3. The population using Use Areas 1, 2, and 3 in GMU 9 can be considered a discrete "herd unit" that is supplemented by animals from GMU 7. Regardless of whether Tables 10, 11, or 12 are examined, greater than 95% of all elk observations that ever occurred in those areas occurred in Areas 1, 2, and 3. In other words, more than 95% of the across season elk movement was self-contained within the herd unit boundary.

The data indicate a 3% level of population transfer (Appendix 12) with Use Areas 8 and 5 located in GMU 7. This level is somewhat misleading in that the transfer amounts, in a large part, to a permanent translocation of animals from GMU 7 to Use Areas 1, 2, and 3 in GMU 9.

Areas 4, 5, 6, 7, 8, 9. The population within GMU 7 (which contains Winter Use Areas 4 and 5, and Summer Use Areas 6, 7, 8, and 9) can be considered a herd unit, but with

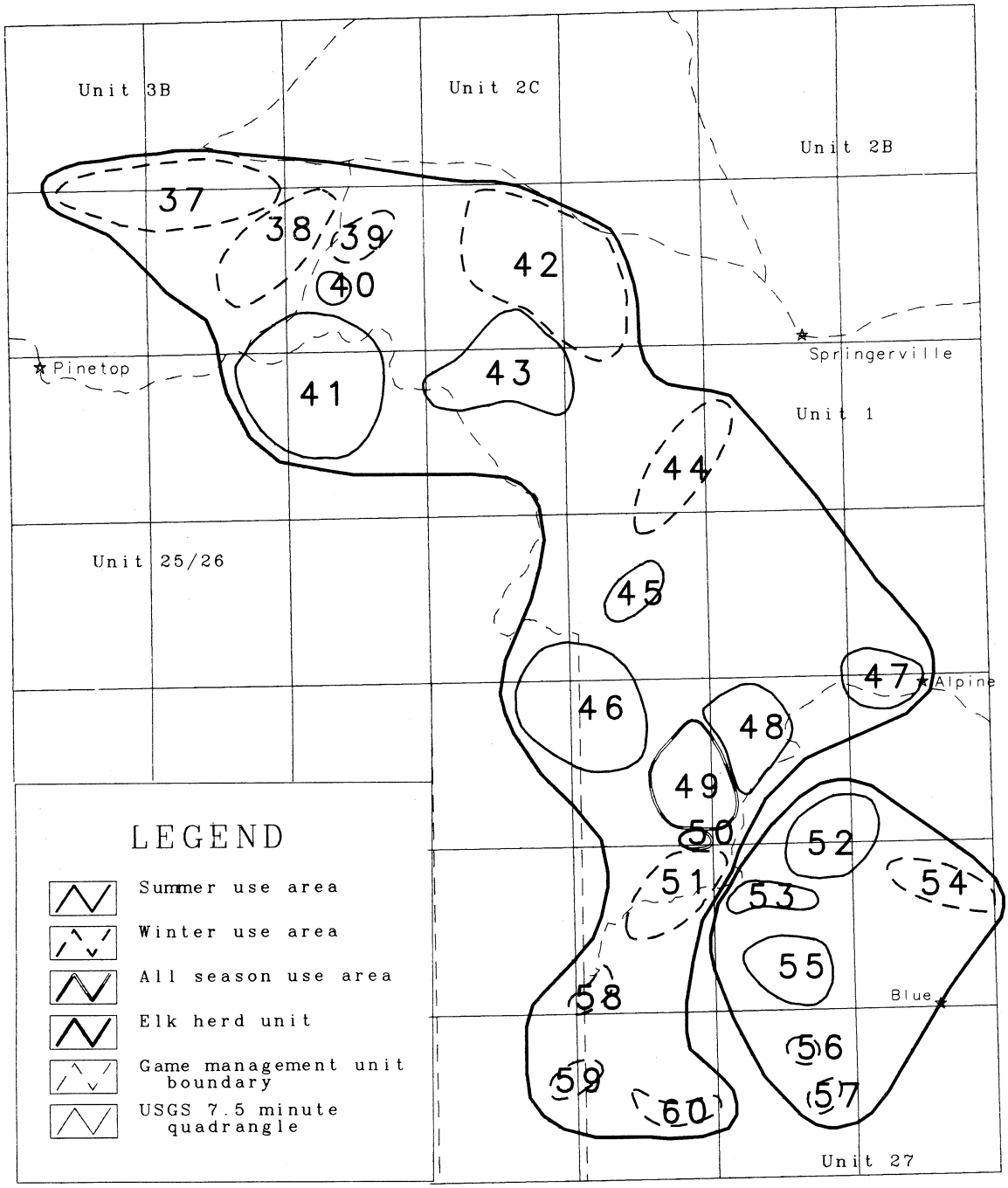

Figure 4. Seasonal use areas and herd unit boundaries of elk occurring within Region I.

the knowledge that some animals are migrating from Unit 7 to Unit 9 in the fall and that about 75% of these is a permanent translocation. Seventy-seven percent (n = 279, Appendixes 10 and 11) of all locations of elk from this herd was self-contained within the herd boundary, and the remaining 23% occurred in Areas 1, 2, and 3.

The combination of Summer Use Areas 6 and 7 shared a high level of across season movement (82%) with Winter Use Area 4 (Table 10). The association of Use Area 6 with Use Area 3 was through one animal that was captured in Area 8, migrated from there to All Season Use Areas 1, 2, and 3 each year, and entered Summer Use Area 6 briefly during one summer.

The 8–9 area combination's primary location for across season transfer of animals was Winter Use Area 5 (Appendix 10), with a noticeable amount of exchange involving the Area 9 portion of the combination with Winter Use Area 4. There was an equally high level of exchange between Area 8 and the All Season 1, 2, and 3 combination but no exchange between Summer Use Area 8 and Winter Use Area 4.

The association between Summer Use Area 8 and All Season Use Areas 1, 2, and 3 was through Winter Use Area 5. Seven radios were installed at Bismark Lake in Use Area 8. Three of these animals consistently wintered in Use Area 5 and returned to Use Area 8 in the summer. The other four migrated through Area 5 into the 1, 2, 3 All Season Area in GMU 9. One of the four wintered there each year and returned to Use Area 8 each summer. The other three remained in the 1, 2, 3 All Season Area year round. A similar move was documented under the W-53-R visibility collar study. A single animal equipped with a visibility collar in GMU 7W was killed by a hunter in GMU 9. It is not known whether this animal represented a permanent translocation or was migrating back and forth seasonally. The telemetry data indicate that permanent translocations, rather than seasonal migrations, are dominating the movements between GMUs 7 and 9 and that GMU 7E is the primary contributor. However, time of capture could be an influencing factor. The translocations occurred as a result of movements from summer to winter range that were not followed by return migrations. Obviously, in the case of a winter trapped population, animals could have transferred before the outset of capture operations.

Seventeen animals were radio instrumented in GMU 7. Six of these were captured in GMU 7W: only one during the summer and five during the winter. If a larger number of elk had been captured and collared in GMU 7W during the summer, some migration or translocation from GMUs 7 to 9 might have been documented. However, the existing radio data indicate that only GMU 7E is a significant contributor to the Unit 9 population, and any estimate of the magnitude of this exchange must be based on the following information.

Eleven animals were captured in 7E: eight during the summer (all four that migrated to Unit 9 came from this group), and three during the winter. No animals captured in GMU 7W migrated to GMU 9. For summer and winter combined, 36% of the animals captured in GMU 7E migrated to GMU 9; 27% of those captured remained in GMU 9. For summer captures only, GMUs 7E and 7W combined, 44% of the animals captured migrated to GMU 9; 33% of those captured remained in Unit 9. No animals that were radio instrumented in GMU 9 migrated to GMU 7.

Areas 10, 12. The population using Areas 10 and 12 in GMU 8 can be considered a discrete herd unit. Elk from this herd were never observed outside of the herd unit boundary. The across season exchange for animals from Use Areas 10 and 12 was entirely with each other (Appendixes 10 and 11). No radio locations for this group were obtained north of Highway I-40, which is the northern boundary of GMUs 8 and 6B. However, local Wildlife Manager Bob Barsch (personal communication) documented nine road killed elk on I-40 between Williams and Flagstaff, Arizona during the July 1986 to June 1989 period. Four of these elk belonged to the nonradio instrumented population using Area 12, which suggests some level of exchange between populations in GMUs 7 and 8

although that level is believed to be unimportant.

Areas 11, 13. The population using Winter Use Area 11 and All Season Use Area 13 should be considered a herd unit. Seventy-eight percent of all locations of elk that ever occupied Areas 11 and 13 occurred within the Areas 11 and 13 combination boundary. The other 22% was located in Area 12, but this group's involvement with Area 12 was rather unimportant in that it is the result of only one observation from one animal. The Areas 11 and 13 combination crosses one GMU boundary. Area 13 falls within GMUs 6B and 8, whereas Area 11 lies entirely within GMU 8.

The primary across season movement for the population in Winter Use Area 11 was to All Season Use Area 13 (57%, Appendix 11). Therefore, a fairly strong migration pattern is established between Areas 11 and 13. The additional use documented for the Area 11 population was due to a single animal that normally summered in Area 12 and wintered in Area 10. This animal was radio tracked over a 37-month period, and it entered Winter Use Area 11 long enough to contribute to one observation. By contributing to a single observation to the area, that animal became part of the Area 11 subpopulation and brought all of its observations into the picture, even though its association with that group was minimal. These periodic forays into adjacent areas are not uncommon and need to be acknowledged on a broad scale. However, the single observation in this case, as well as those occurring in other use areas, may be considered an outlier and excluded from consideration.

The "basic" population for Areas 11 and 13 was radio marked under the W-53-R study. It consisted of five animals, one of which was tracked for only 6 months and another for 17 months. The remaining three were tracked over a normal radio life span, but there was a 10-month gap in the tracking that occurred between the end of the W-53-R study and the beginning of this study. This lack of data reduced the number of potential observations and made these population data more sensitive than they might have been. If this animal's single observation in Area 11 is ignored, then the across season level of population exchange is 100% between Areas 11 and 13 (Appendixes 11 and 12). Also, the seasonal use area fidelity rating increases to 50% and the other 50% is accounted for by Area 13.

Again, no radio locations for this group were obtained north of Highway I-40. However, four of the road kills reported by Barsch (personal communication) were from the Use Area 13 population. Additionally, during this study, a nonradio instrumented animal wearing an ear tag, which was installed at the Navajo Army Depot (Area 13) 5 years earlier, was killed by an automobile on I-40, just west of the Army Depot. During the W-53-R visibility collar study, additional movement from the Army Depot (Use Area 13) to GMUs 7 and 8 was documented. Visibility collars were installed on 126 elk at this location. Between 1978 and 1983, this group provided three return sightings in GMU 7E (Use Areas 5, 8); three in GMU 7W (Use Areas 6, 7); two more just north of I-40; and five in GMU 8 (Use Area 12). These sightings suggest some level of exchange between Use Area 13 and GMU 7.

The visibility collar study indicated that the Area 13 herd was heavily involved with the Rogers Lake region just north of Use Area 14 and that the herd's range probably extends further east, as indicated by the broken line in Figure 3. However, the Rogers Lake group has not been studied.

Area 14. The population using Area 14 was a discrete nonmigratory herd that remains entirely within the boundaries of GMU 6B. There is some "transient" activity through the area however. A considerable amount of its subpopulation's time expenditure (36%) went to Area 19 in the summer (Appendix 7), and to Area 16 (27%) in the winter (Appendix 6). However, there is a similarity to the situation that was described in the Areas 11 and 13 discussion. Three "outside animals" entered Area 14 and contributed to one observation each, then moved on and never returned. Subsequently, they were included in the subpopulation, but were transients rather than migrants that truly belong to the Area 14 subpopulation.

All others, the primary population, were nonmigrants with 100% fidelity to Area14.

Areas 15, 16, 17, 18, 19, 20, 21, 22, 36. The interaction between Areas 15, 16, 17, 18, 19, 20, 21, 22, and 36 is so great that the entire aggregation must be considered as a single entity (herd unit). No single use area contributed more than 67% of its population's time expenditure to any other single area; for one area, the highest level of across season exchange with any other area was only 36%. A total of 900 observations were recorded for the subpopulation of all of these areas, and 93.8% (845) occurred within the herd unit boundary. Use Area 23 received about 3% of the aggregation's across season use level; Areas 24 and 32 received about 1% each; Areas 14, 26 and 29 each received less than 1%. This combination of use areas involved portions of GMUs 6A, 5BN, and 5BS.

Exchange of elk between the herd's seasonal use areas was high. The Area 15 subpopulation's across season movement was entirely to Summer Use Area 19 (Appendix 11). Winter Use Area 16 has a strong across season association with Area 19 (Appendix 11). Only 30% of that subpopulation's summer use level went to areas other than Areas 16 or 19. However, the exchange levels with Areas 20 and 36 are noteworthy.

Area 20 was the major use area for across season movement from Winter Use Areas 17 and 18 combined (Appendix 11). However, Summer Use Areas 19 and 21 received considerable amounts of the subpopulation's time expenditure with six additional use areas receiving lesser amounts.

The primary across season movement of elk from Area 19 was to Area 16 (Appendix 10). Areas 16 and 19 together accounted for 72% of the subpopulation's winter time expenditure. A significant amount went to Area 15 as well. Thus, a strong migrational association between Areas 19 and 16 and 19 and 15 exists, with minor association between Area 19 and seven other areas (each less than 2%).

The Area 20 subpopulation's across season movements involve 10 other use areas, none of which received in excess of 36% of the subpopulation's winter use (Appendix 10). In several cases, animals that used Area 20 during the summer wintered in an area to the west for 1 year and then changed to a winter area on the east the following year, or vice versa.

The Area 21 subpopulation's level of across season exchange was 100% with the Winter Use Areas 17 and 18 combination. The major area for across season movement for Area 22 was to Summer Use Area 36, which received 45% of the population's time expenditure, and to Area 20, which received 40% (Appendix 11). Three other areas, none of which exceeded 9%, received the remainder.

Area 36 subpopulation's across season movement was primarily to Winter Use Area 16 (45%). Six additional areas received portions of its populations use level.,Two of these, Areas 22 and 17, received considerable amounts (Appendix 10).

Areas 23, 24, 25, 26, 27. The interaction between populations from Areas 23, 24, 25, 26, and 27 indicates that this combination can be considered as a herd unit. No single area contributed more than 28% of its subpopulation's across season observations to any other area (Appendixes 11, 12, 13, and 14). However, when combined (Appendixes 11, 13, and 14), 270 of the 297 observations (90.9%) from this aggregation were self-contained. Area 19 contained 5% of the total observations, Area 21 received 3%, and Areas 16 and 17 less than 1%. This combination involves portions of GMUs 5BS and 5A.

The main area for across season movement from Area 23 was to Summer Use Area 19, which contained 23% of Area 23 subpopulation's time expenditure; Area 24 contained 18%, and Area 26 contained 17%. Five additional areas contained fewer observations (Appendix 9).

Area 24 subpopulation's across season exchange was almost entirely with the Area 25, 26, 27 complex (Appendix 12). The greatest level of exchange occurred during the summer period, indicating that winter use predominates over summer in this particular area (Appendixes 13 and 14). Another study has demonstrated (Brown 1988) that winter populations are at least three times as great as

summer levels in this area. Despite the small sample of migrants, information on time of migration (Appendixes 19 and 20) is in agreement with Brown's 1988 study.

Areas 25, 26, and 27 are combined; the combination qualifies as an All Season Range Use Area despite the fact that it is usually thought of as summer range. However, the higher fidelity rating (85%) during the June–August period (Appendix 6), as opposed to 61% for January–March (Appendix 6), demonstrates a greater tendency toward summer use. Regardless of whether it is classified as an all season or a summer use area, the combination's major population exchange was with Use Areas 23 and 24 (Appendixes 12 and 13).

Areas 28, 29, 30. Little is known about the Areas 28, 29, 30 complex in GMU 5BN. However, existing data suggest that the complex also may be included in the Areas 15–36 herd. This aggregation of areas is located on the Raymond Buffalo Ranch just off the edge of Anderson Mesa, which is usually considered winter range that supports a few year round residents. This study classifies two of these areas (probably incorrectly) as summer range because of small sample size (Appendix 1). The majority of data points were contributed by only two animals, both year round residents. One of these spent its summers in the bottom of Canyon Diablo (Area 30), just west of Meteor Crater. The other resident spent most of its time in Area 29, but wintered in Area 28 as did the Canyon Diablo animal. When Areas 28, 29, and 30 are combined, the combination qualifies as an all season use area. The only other animals that contributed data to the Areas 28, 29, 30 combination normally spent their summers in Use Area 36. However, during the final year of radio tracking it moved into Areas 28, 29, and 30 during January and February. This all season use area's major subpopulation movement seems to be to Summer Use Area 36 and to a lesser degree to Winter Use Area 22 (Appendix 12). The previous visibility collar study suggested a slight connection between elk occupying Anderson Mesa northwest of Areas 28, 29, and 30 and those north of Areas 36 and 19. No further data have been collected on this Anderson Mesa group.

Areas 31, 32. The subpopulation using Areas 31 and 32 appeared to be a herd unit having some interaction with the subpopulation in Use Areas 17 and 18. Of its subpopulation's across season exchange, 88% was contained within the herd unit boundary (Appendixes 10 and 11). Area 18 received 8% of its across season use, and Area 17 received 4%. This herd resides in both GMU 6A and GMU 22.

Primary across season movement for the Area 32 subpopulation was to Area 31, with 17% and 9% of the use going to Winter Use Areas 18 and 17, respectively (Appendix 10). Across season use for the Area 31 population was entirely within Area 32 (Appendix 11).

Areas 33, 34. The population using Areas 33 and 34 can be considered as a herd unit. The across season exchange for these areas was 100% self-contained (Appendixes 8 and 9). This herd occupied both GMUs 23 and 4A. However, few if any of the observations occurred further than 10 km within the border of GMU 4A. Across season use for the Area 33 population was entirely within Area 34; across season use for the Area 34 population was entirely within Area 33 (Appendixes 8 and 9).

Areas 37 through 51, 58, 59, 60. The population using Winter Use Areas 37, 38, 39, 42, and 44; Winter Use Areas 51, 58, 59, and 60; All Season Use Areas 49 and 50; and Summer Use Areas 40, 41, 43, 45, 46, 47, and 48 can be considered a herd unit. All observations were contained within the herd unit boundary (Appendixes 10, 11, 13 and 14).

Winter Use Areas 37, 38, 39, 42, and 44 population's across season movement was to Use Areas 40, 41, 43, 45, and 46, which were tied to Areas 47 and 48 through an improved fidelity rating. The Summer Range of the Areas 40, 41, 43, 45, 46, 47, and 48 population's across season movement was primarily to Areas 37, 38, 39, 42, and 44. However, 31% went to Areas 51, 58, 59, and 60. The two small All Season Use Areas 49 and 50, on either a "within" or "across" season basis, are associated with the Areas 43, 45, 46, 47, 48, and 51, 58, 59, 60 aggregations. Winter Use

Areas 51, 58, 59, 60 across season exchange was primarily with the 43, 45, 46, 47, 48 aggregation.

Areas 52, 53, 54, 55, 56, 57. The population using Winter Use Areas 54, 56, and 57 and Summer Use Areas 52, 53, and 55 can be considered a herd unit. Across season observations for these aggregations totaled 78 and were 100% contained within the herd boundary (Appendixes 10, 11).

Areas 52, 53, and 55 across season exchange was entirely with Areas 54, 56, and 57. Winter Use Areas 54, 56, and 57 across season exchange was entirely with Areas 52, 53, and 55.

GMUs 4A and 4B. No elk were equipped with radio transmitters in either of these units because of the amount of visibility collar work they received under the W-53-R study. The majority of those observations of elk, marked at three separate trap sites in GMU 4A, were confined to GMU 4A (Figures 5, 6, and 7). However, some elk from each of these trap sites were located in GMU 5A. Elk from the Pinto Lake trap site (GMU 4B) were located in 4A in substantial enough numbers within the two GMUs to be considered a single herd (Figures 8, 9).

DISCUSSION

Shoesmith (1979) determined that individual elk in a Montana study were found together only "about as frequently as expected by chance." Other investigators (Harper 1964, Struhsaker 1967, and Knight 1970) also reported that the social structure within groups of elk is unstable and that individuals frequently move from one group to another. However, repeat or habitual use of seasonal home ranges has been reported (Murie 1951, Brazda 1953, Anderson 1958, Picton 1960, Tanner 1965, Knight 1970, Craighead et al. 1972, Shoesmith 1979, and Waldrip and Shaw 1979). Murie believed that this habitual use is the result of familial behavior learned as calves.

In this study coefficient of association tests were not used, as did Shoesmith (1979), to examine the frequency of contact between individual elk. However, observations did not suggest any tendency for individuals occupying any particular use area to maintain any particular level of contact with other radio marked individuals. Nevertheless, there was a strong tendency for individuals to occupy the

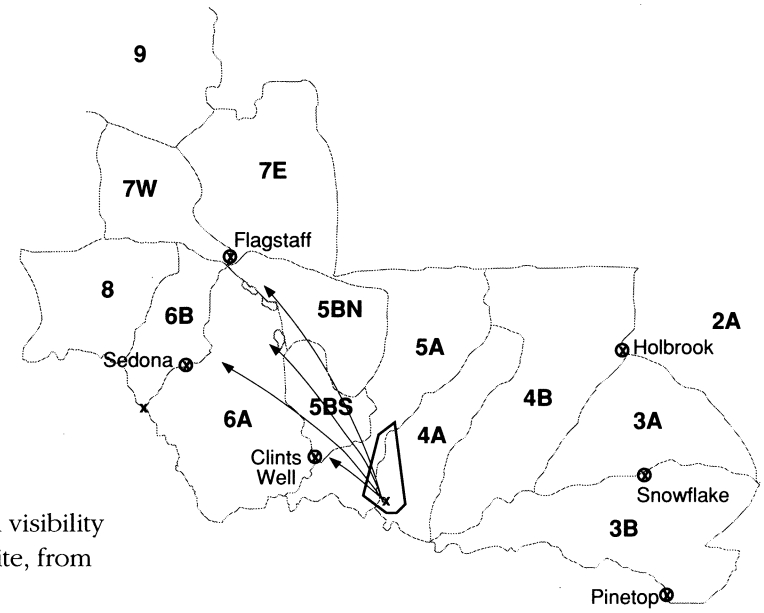

Figure 5.
Observations of elk equipped with visibility collars in GMU 4A, Fairchild trap site, from July of 1976 through June of 1982.

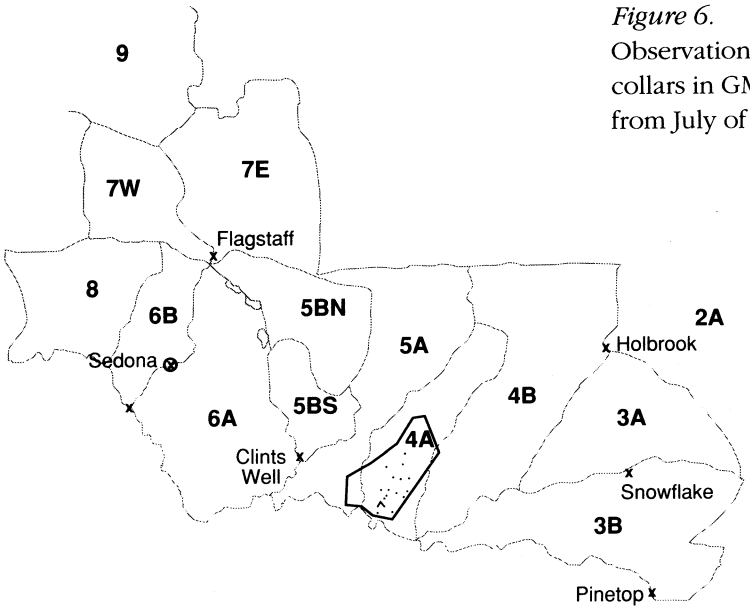

Figure 6.
Observations of elk equipped with visibility collars in GMU 4A, Vincent Ranch traps site, from July of 1976 through June of 1982.

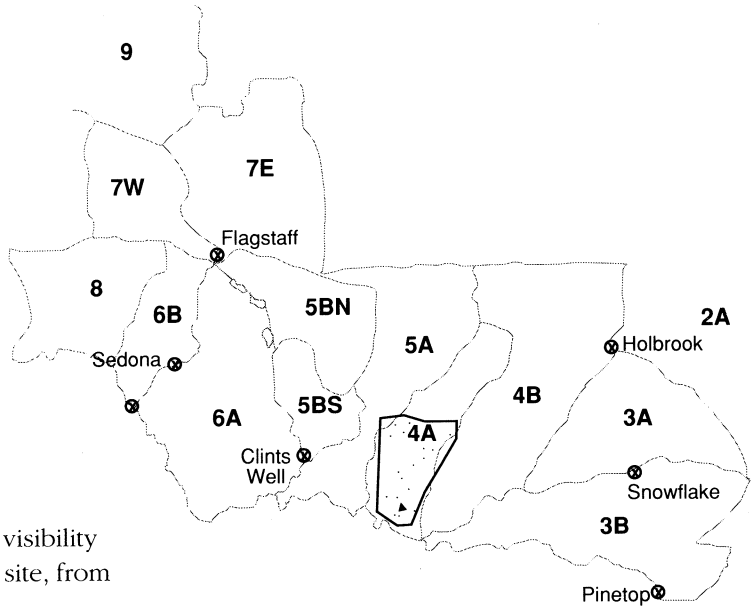

Figure 7.
Observations of elk equipped with visibility collars in GMU 4A, Dye Ranch trap site, from July of 1976 through June of 1982.

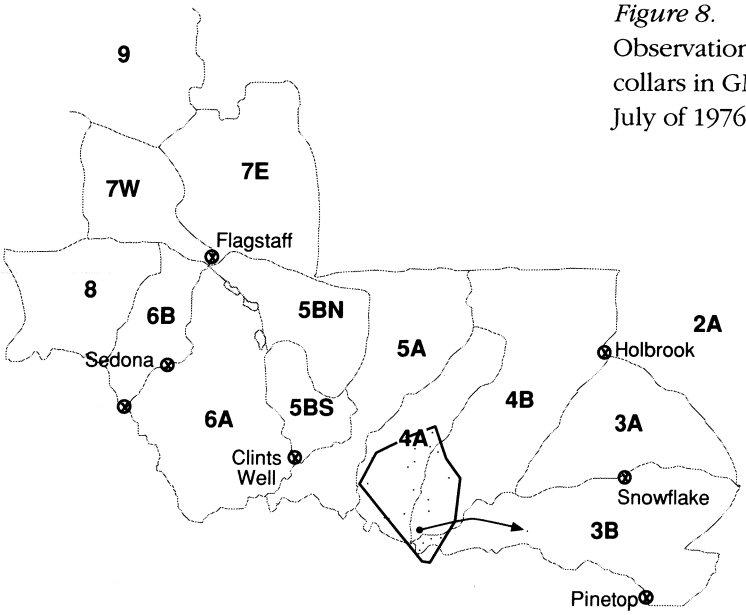

Figure 8.
Observations of elk equipped with visibility collars in GMU 4A, Pinto Lake trap site, from July of 1976 through June of 1982.

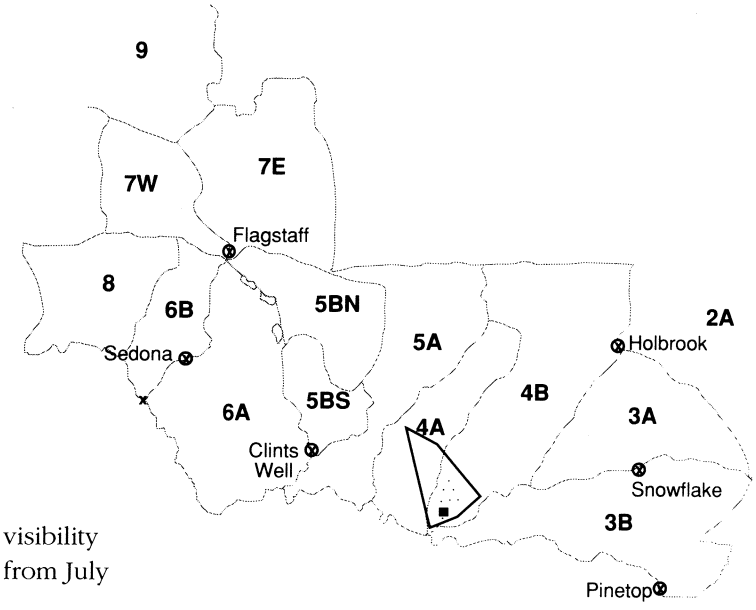

Figure 9.
Observations of elk equipped with visibility collars in GMU 4A, St. Joe trap site, from July of 1976 through June of 1982.

same seasonal use areas each year, and seasonal observations tended to clump into discrete clusters. Subsequently, there appears to be a high degree of fidelity to particular geographical areas but not to social groups within those areas.

Genetic isolation could be one possible consequence of a high degree of fidelity to any geographic area. The apparent frequent exchange of individuals between seasonal use areas may be one of the primary mechanisms that prevents extensive inbreeding. Even though we were able to identify units that in some cases appear to be 95 to 100% self-contained, these units encompass areas broad enough to hold a substantially large gene pool. Within these herd unit boundaries there are usually two or more use areas that exchange individuals, and within each use area are social aggregations that exchange individuals on a frequent basis. Shoesmith (1979) found that exchange of individuals between social groups was common even during the breeding season, with cows usually remaining in the same harem for less than 5 days.

Seasonal migrations are triggered by snow depth and forage availability. The most abrupt migrations witnessed during this study were induced by changes in weather patterns during late fall or early winter. There is ample documentation that early winter snow accumulation is the most common triggering mechanism for migrations to winter range (Mitchell and Lauckhart 1948, Anderson 1958, Lovaass 1970, Picton and Picton 1975, and Schwartz and Mitchell 1945). Leege and Hickey (1977) report that in Idaho, 46–61 cm (around 1.5 to 2 feet) of snow accumulation was enough to induce elk to move. Snow depths were not obtained during this study; however, it appeared that Arizona elk migrated in response to less snow than reported in the Idaho study, perhaps as little as 30 cm (about 1 foot). As previously mentioned, a reversal of the weather pattern (usually rapid snow melt) on several occasions resulted in a reverse migration back to summer range. This reverse migration may have been due to more or better quality forage (perhaps a result of snow melt) still being available at higher elevations. It also could be in response to daytime temperatures.

Ward et al. (1973) and Dalke et al. (1956) report that spring migrations back to summer range are controlled by the rate of green up and availability of new forage at higher elevations. Skinner (1925) and Dalke et al. (1956) have reported reverse spring migrations in response to local forage conditions. No reversal of the spring migration pattern was witnessed during the Arizona study.

Although some elk are year round residents in certain localities, the majority of Arizona's elk are migratory. This migration ensures forage availability at all times of the year and also distributes total grazing pressure over a larger area on a year round basis. This latter aspect has been stressed by both Martinka (1969) and Craighead et al. (1972) as being very important to winter range maintenance in Idaho (i.e., providing adequate rest to the winter range plant community during the summer months). It is undoubtedly equally important in Arizona—particularly in areas with extensive cool season grass communities. The areas identified in this study as "All Season Use Areas" may be vulnerable to range overuse because elk are using them to a significant degree during both summer and winter.

Migration times are predictable only in a very general fashion. Certain range allotments are therefore more vulnerable than others to any fluctuations in this respect. Additionally, the management of hunting seasons is complicated by these same inconsistencies. This report is intended to help local managers identify problem areas and find solutions for the same.

The data in this report were obtained almost entirely from female animals. Only three males were included in the study. The male segment of the population remains detached from female social groups throughout most of the year. Nevertheless, these three individuals occupied the same use area combinations as their female counterparts, and at this time there is no reason to suspect differing migration routes or use area involvement between the two sexes.

MANAGEMENT OPTIONS

Survey And Set Harvest Levels By GMU Only

This approach coupled with uniform starting and ending dates for hunting seasons has been the basic form of management over the past few years. The uniform date frame for the general hunt prevents any group of elk from being exposed to more than one general firearms hunt, even though they may migrate across a GMU boundary. Archery and muzzleloader hunts occur at earlier dates so there is the possibility that a group of elk could be exposed to a primitive weapon hunt in one GMU and a general firearms hunt in another. However, most GMUs have primitive weapon hunts that are also restricted to a uniform date frames; thus, the latter point may not carry much significance.

The main advantages to this approach are administrative. GMU boundaries are clearly defined (usually by roads) and easily recognized by the general public. The disadvantages are that elk herds may migrate across these boundaries and be harvested in more than one GMU. Also, survey data from a particular GMU may involve more than one herd, or the herd to which it applies may not be present once a migration has occurred.

Delineate Elk Hunt Boundaries According To Elk Herd Boundaries

Each herd is surveyed, and harvest levels are based on those data separately—clearly the most desirable option from the biological standpoint. However, it may be impossible to administer because of the lack of recognizable (to the public) geographical features that would define herd unit boundaries.

Establish Uniform Hunt Dates for Adjacent GMUs That Provide Habitat To The Same Herd.

Managers would coordinate survey activities so that data would be compatible with the herd unit boundaries. Any combination of GMUs that contains the same herd unit could be hunted during different date frames than an adjacent set of GMUs that support a different herd. Permit allocation and harvest levels would be set by considering a block of GMUs that contains a herd unit. This approach should satisfy both biological and administrative requirements.

Establish Uniform Hunt Dates Across All GMUs, And Coordinate Surveys For Each Herd Separately

This approach is the same as above except that it lacks the flexibility that would allow certain combinations of GMUs to be hunted during different time frames than others. It more closely resembles our current management strategy but may not be quite as sophisticated for controlling harvests as the option above.

Special Control Hunts

If special hunts are used to control locally high concentrations of elk, the data suggest that for maximum effectiveness, such hunts should be conducted in January—weather and road conditions permitting. During December, a substantial amount of movement is still in progress during years of late migration, and elk from nontarget herds could be harvested.

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Appendix 1. Seasonal use area designation, based on ≥ 67% of the observations contributed to each use area by that area's subpopulation, during winter (January-March) and summer (June-August).

Area	Winter % (No.)	Summer % (No.)	Designation	Area	Winter % (No.)	Summer % (No.)	Designation
1	25 (7)	75 (21)	Summer	31	94 (15)	6 (1)	Winter
2	92 (22)	8 (2)	Winter	32	7 (2)	93 (25)	Summer
3	38 (40)	62 (64)	All Season	33	93 (41)	7 (7)	Winter
4	100 (33)	0 (0)	Winter	34	10 (7)	90 (93)	Summer
5	100 (34)	0 (0)	Winter	36	9 (6)	91 (58)	Summer
6	0 (0)	100 (21)	Summer	37	100 (11)	0 (0)	Winter
7	0 (0)	100 (11)	Summer	38	100 (3)	0 (0)	Winter
8	0 (0)	100 (48)	Summer	39	100 (8)	0 (0)	Winter
9	0 (0)	100 (16)	Summer	40	0 (0)	100 (1)	Summer
10	100 (32)	0 (0)	Winter	41	0 (0)	100 (22)	Summer
11	100 (11)	0 (0)	Winter	42	100 (43)	0 (0)	Winter
12	7 (4)	93 (55)	Summer	43	0 (0)	100 (36)	Summer
13	46 (11)	54 (13)	All Season	44	100 (3)	0 (0)	Winter
14	59 (48)	41 (34)	All Season	45	0 (0)	100 (7)	Summer
15	87 (26)	13 (4)	Winter	46	0 (0)	100 (13)	Summer
16	92 (84)	8 (7)	Winter	47	0 (0)	100 (9)	Summer
17	100 (49)	0 (0)	Winter	48	18 (3)	82 (14)	Summer
18	100 (12)	0 (0)	Winter	49	50 (3)	50 (3)	All Season
19	10 (23)	90 (199)	Summer	50	(0)	(0)	All Season
20	5 (4)	95 (82)	Summer	51	100 (11)	0 (0)	Winter
21	2 1(4)	79 (15)	Summer	52	32 (6)	68 (13)	Summer
22	74 (26)	26 (9)	Winter	53	0 (0)	100 (5)	Summer
23	89 (50)	11 (6)	Winter	54	100 (6)	0 (0)	Winter
24	54 (39)	46 (33)	All Season	55	0 (0)	100 (4)	Summer
25	3 (7)	70 (16)	Summer	56	100 (5)	0 (0)	Winter
26	50 (11)	50 (11)	All Season	57	100 (7)	0 (0)	Winter
27	50 (27)	50 (27)	All Season	58	100 (3)	0 (0)	Winter
28	100 (24)	0 (0)	Winter	59	100 (7)	0 (0)	Winter
29	18 (4)	82 (18)	Summer	60	100 (8)	0 (0)	Winter
30	0 (0)	100 (10)	Summer				

Appendix 2. Number of telemetered elk comprising each use area's subpopulation.

Area	Winter (January-March)	Summer (June-August)	Area	Winter (January-March)	Summer (June-August)
1	4	4	31	3	3
2	5	5	32	4	4
3	9	9	33	6	6
4	5	5	34	6	6
5	9	9	36	9	9
6	6	6	37	3	0
7	2	2	38	3	0
8	10	10	39	1	0
9	6	6	40	0	1
10	5	5	41	0	3
11	5	4	42	6	0
12	5	5	43	0	6
13	4	4	44	1	0
14	8	8	45	0	1
15	5	5	46	0	3
16	24	25	47	0	1
17	10	10	48	2	2
18	6	6	49	2	2
19	24	24	50	0	0
20	15	16	51	3	0
21	4	4	52	2	2
22	11	11	53	0	2
23	10	10	54	2	0
24	5	5	55	0	1
25	7	8	56	2	0
26	8	8	57	2	0
27	9	9	58	2	0
28	2	2	59	2	0
29	2	2	60	1	0
30	1	1			

Appendix 3. Distribution of elk observations among summer (June-August) use areas used by elk that originated from a given summer use area. Observations are presented as percentages of all summer observations, with the number of observations presented in parentheses.

Summer Use Area	Self % (No.)	Area % (No.)	Area % (No.)	Area % No.)	Area % (No.)	Area % (No.)	Total No. Locations
1	58 (21)	3 36 (13)	2 6 (2)				36
6	48 (21)	7 25 (11)	8 18 (8)	9 5 (2)	3 5(2)		44
7	79 (11)	9 14 (2)	6 7 (1)				14
6 & 7	76 (44)	8 14 (8)	9 7 (4)	3 3 (2)			58
8	64 (48)	1 28 (21)	3 4 (3)	9 4 (3)			75
9	47 (16)	8 50 (17)	6 3 (1)				34
8 & 9	77 (84)	1 19 (21)	3 3 (3)	6 1 (1)			109
12	100 (55)						55
19	87 (199)	36 7 (16)	16 3 (6)	15 2 (4)	21 1(2)		227
20	54 (82)	36 28 (42)	22 7 (11)	26 4 (6)	21 3(4)	19 2(3)	
		16 1 (1)	23 1 (2)				151
21	83 (15)	18 6 (1)	19 6 (1)	32 6 (1)			18
25	31 (16)	27 39 (20)	24 30 (15)				51
29	28 (9)	36 72 (23)					32
30	100 (5)						5
29 & 30	63 (39)	36 37 (23)					62
32	86 (25)	21 14 (4)					29
34	100 (63)						63
36	48 (58)	19 43 (52)	20 4 (5)	22 4 (6)	31 1(1)		123
40	10 (1)	41 90 (9)					10
41	67 (22)	43 30 (10)	40 3 (1)				33
40 & 41	77 (33)	43 23 (10)					43
43	67 (36)	48 17 (9)	45 13 (7)	46 3 (2)			54
45	78 (7)	46 22 (2)					9
46	44 (13)	47 30 (9)	45 23 (7)	49 3 (1)			30
47	90 (9)	46 10 (1)					10
48	50 (14)	47 32 (9)	43 7 (2)	49 7 (2)	46 4(1)		28
43,45,46	79 (74)	47 10 (9)	48 10 (9)	49 1 (1)			93
47 & 48	85 (32)	43 5 (2)	46 5 (2)	49 5 (2)			38
43,45,46, 47,48	98 (128)	49 2 (3)					131
40,41,43, 45,46,47, 48	98 (171)	49 2 (3)					74
52	93 (13)	53 7 (1)					14
53	23 (5)	52 59 (13)	55 18 (4)				22
55	50 (4)	53 50 (4)					8
52,53,55	100 (44)						44

Appendix 4. Distribution of elk observations among winter (January-March) use areas used by elk that originated from a given winter use area. Observations are presented as percentages of all winter observations with the number of observations presented in parentheses.

Winter Use Area	Self % (No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Total No. Locations
2	61 (22)	1	19 (7)	3	17 (6)	5	3 (1)					36
4	100 (33)											33
5	67 (34)	1	14 (7)	2	14 (7)	3	6 (3)					51
10	91 (32)	12	9 (3)									35
11	38 (11)	13	38 (11)	10	21 (6)	12	3 (1)					29
15	76 (26)	19	12 (4)	16	9 (3)	23	3 (1)					34
16	58 (84)	17	18 (27)	19	11 (16)	15	5 (7)	22	3 (4)	14	1(2)	
		20	1 (2)	23	1 (1)	36	2 (3)					146
17	49 (49)	24	18 (18)	16	9 (9)	18	8 (8)	22	5 (5)	21	5 (5)	
		20	4 (4)	19	2 (2)							100
18	32 (12)	17	32 (12)	21	16 (6)	31	14 (5)	32	3 (1)	20	3 (1)	37
17 & 18	60 (81)	24	13 (18)	21	8 (11)	16	7 (9)	20	4 (5)	22	3 (5)	
		31	3 (5)	19	1 (2)	32	1 (1)					137
22	37 (26)	17	27 (19)	16	13 (9)	36	8 (6)	23	7 (5)	20	3 (2)	
		29	3 (2)	19	3 (2)							71
23	48 (50)	24	13 (14)	19	8 (8)	16	8 (8)	26	7 (7)	18	5 (5)	
		15	4 (4)	21	3 (3)	17	2 (2)	22	2 (2)	14	1 (1)	104
28	100 (12)											12
31	88 (15)	32	12 (2)									17
33	85 (41)	34	15 (7)									48
37	48 (11)	39	35 (8)	38	13 (3)	42	4 (1)					23
38	13 (3)	37	48 (11)	39	35 (8)	42	4 (1)					23
39	80 (8)	37	10 (1)	38	10 (1)							10
42	86 (43)	37	6 (3)	44	6 (3)	38	2 (1)					50
44	33 (3)	42	67 (6)									9
37,38,39	96 (54)	42	4 (2)									56
42 & 44	93 (55)	37	5 (3)	38	2 (1)							59
37, 38, 39, 42, & 44	100 (115)											115
54	50 (6)	52	50 (6)									12
56	42 (5)	57	58 (7)									12
57	58 (7)	56	42 (5)									12
56 & 57	100 (24)											24
54,56,57,	83 (30)	52	17 (6)									36
51	31 (11)	60	22 (8)	59	20 (7)	48	9 (3)	49	9 (3)	58	9 (3)	35
58	11 (3)	51	41 (11)	59	26 (7)	48	11 (3)	49	11 (3)			27
59	39 (7)	51	44 (8)	48	6 (1)	49	6 (1)	58	6 (1)			18
58 & 59	40 (18)	51	42 (19)	48	9 (4)	49	9 (4)					45
51,58,59	72 (58)	60	10 (8)	48	9 (7)	49	9 (7)					80
60	100 (9)											9
51,58,59, & 60	84 (75)	48	8 (7)	49	8 (7)							89

Appendix 5. Distribution of elk observations among use areas used by elk that originated from a given all season (January-March and June-August) use area. Observations are presented as percentages of the total all season observations, with the number of observations presented in parentheses.

All Season Use Area	Self % (No.)	Area	% (No.)	Area	% (No.)	Area	% (No.)	Area	% (No.)	Area	% (No.)	Total No. Locations
3	63 (104)	1	17 (28)	2	15 (24)	8	5 (8)	5	1 (1)			165
1 & 3	78 (178)	2	17 (40)	5	1 (2)	8	4 (8)					223
13	69 (24)	11	31 (11)									35
14	57 (82)	19	23 (34)	16	12 (18)	13	6 (8)	11	2 (3)			145
24	83 (72)	25	11 (9)	17	2 (2)	26	2 (2)	27	2 (2)			87
26	19 (22)	27	38 (45)	23	37 (43)	25	5 (6)	19	1 (1)			117
27	52 (54)	25	17 (18)	23	17 (17)	26	12 (12)	19	1 (1)	17	1 (1)	103
26 & 27	60 (133)	23	27 (60)	25	11 (24)	17	1 (1)	19	1 (2)			220
25,26,27	71 (228)	23	17 (55)	24	11 (34)	17	1 (2)	19	1 (2)			321
28,29,30	64 (56)	36	30 (26)	22	6 (5)							88
49	8 (6)	48	23 (17)	46	15 (11)	51	15 (11)	47	12 (9)	60	11 (8)	
		59	9 (7)	58	4 (3)	43	3 (2)					74
50	0 (0)	48	20 (12)	46	19 (3)	51	19 (3)	47	1 5(9)	59	12 (7)	
		49	7 (4)	58	5 (3)	43	3 (2)					59

Appendix 6. Distribution of elk observations among use areas used by elk that originated from a given all season (January-March) use area. Observations are presented as percentages of the total all season observations, with the number of observations presented in parentheses.

All Season Use Area	Self % (No.)	Area	% (No.)	Area	% (No.)	Area	% (No.)	Area	% (No.)	Area	% (No.)	Total No. Locations
3	57 (40)	2	32 (22)	1	10 (7)	5	1 (1)					70
1 & 3	61 (59)	2	37 (36)	5	2 (2)							97
13	50 (11)	11	50 (11)									22
14	55 (34)	16	27 (17)	19	7 (4)	13	6 (4)	11	5 (3)			62
24	95 (39)	17	5 (2)									41
26	15 (11)	23	49 (35)	27	29 (21)	25	7 (5)					72
27	47 (27)	23	27 (16)	25	13 (7)	26	13 (7)	17	2 (1)			58
26 & 27	51 (66)	23	39 (51)	25	9 (12)	17	1 (1)					130
25,26,27	61 (113)	23	28 (51)	24	10 (19)	17	1 (2)					185
28,29,30	78 (28)	22	14 (5)	36	8 (3)							36
49	9 (3)	51	31 (11)	60	22 (8)	59	20 (7)	48	9 (3)	58	9 (3)	35
50	0 (0)	51	41 (11)	59	26 (7)	48	11 (3)	49	11 (3)	58	11 (3)	27

Appendix 7. Distribution of elk observations among use areas used by elk that originated from a given all season (June-August) use area. Observations are presented as percentages of the total all season observations, with the number of observations presented in parentheses.

All Season Use Area	Self %(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Total No. Locations
3	67 (64)	1	22 (21)	8	9 (8)	2	2 (2)					95
1 & 3	91 (119)	8	6 (8)	2	3 (4)							131
13	100 (13)											13
14	58 (48)	19	36 (30)	13	5 (4)	16	1 (1)					83
24	72 (33)	25	20 (9)	26	4 (2)	27	4 (2)					46
26	28 (11)	27	60 (24)	23	8 (3)	19	2 (1)	25	2 (1)			40
27	60 (27)	25	25 (11)	26	11 (5)	19	2 (1)	23	2 (1)			45
26 & 27	79 (67)	25	14 (12)	23	5 (4)	19	2 (2)					85
25,26,27	85 (115)	24	11 (15)	23	3 (4)	19	1 (2)					136
28,29,30	55 (28)	36	45 (23)									51
49	8 (3)	48	36 (14)	46	28 (11)	47	23 (9)	43	5 (2)			39
50	0 (0)	46	35 (11)	47	28 (9)	48	28 (9)	43	6 (2)	49	3 (1)	32

Appendix 8. Distribution of elk observations among game management units (GMU) occupied by elk that originated from a given GMU. Observations are presented as percentages of all observations (entire study period), with the number of observations presented in parentheses.

GMU	Self %(No.)	GMU	%(No.)	GMU	%(No.)	GMU	%(No.)	GMU	%(No.)	GMU	%(No.)	Total No. Locations
1	73 (336)	25	13 (60)	27	7 (31)	3B	7 (32)					459
3A												
3B[b]	24 (33)	25	30 (42)	1	19 (27)	23	10 (14)	4B	9 (12)	4A	8 (11)	139
4A[a]	43 (86)	23	45 (89)	4B	12 (24)	3B	tr. (1)					200
4B[a]	16 (24)	4A	42 (64)	23	41 (63)	3B	1 (1)					152
5A	68 (381)	5BS	20 (114)	22	6 (33)	6A	5 (29)	5BN	1 (1)			558
5BN	29 (72)	5BS	59 (147)	6A	12 (30)	5A	tr. (1)					250
5BS	46 (364)	6A	33 (258)	5A	19 (150)	5BN	2 (17)	6B	tr. (2)			791
6A	72 (883)	5BS	16 (194)	5A	8 (100)	22	3 (33)	5BN	1 (12)	6B	tr.(2)	1224
6B	53 (214)	8	24 (99)	6A	22 (89)	5BS	1 (2)	7E	tr. (1)			405
7E	53 (172)	9	33 (109)	8	8 (26)	6B	4 (14)	7W	2 (5)			326
7W	61 (155)	7E	26 (65)	9	11 (28)	10	2 (6)					254
8	84 (289)	6B	16 (54)	7E	tr. (1)							344
9	75 (322)	7E	24 (103)	7W	1 (3)	11	tr. (1)					429
10	40 (6)	7W	60 (9)									15
11[b]	2 (1)	9	98 (42)									43
22	41 (33)	6A	33 (26)	5A	26 (21)							80
23	44 (89)	4A	43 (86)	4B	12 (24)	3B	1 (1)					200
25[b]	21 (66)	1	65 (202)	3B	10 (32)	27	4 (11)					311
27[b]	49 (127)	1	48 (124)	25	3 (9)							260

[a] No animals instrumented in this unit. Data apply only to that portion of the population whose migration patterns cross the rim.

[b] No animals instrumented in this unit. Data obtained only from animals that moved into the respective unit from outside areas.

Appendix 9. The percent of elk locations, of a use area's subpopulation, that remained within that use area.

SUMMER USE AREAS

Use Area	June-August %	June-September %	June-September Difference[a]	September %	September Difference[a]	October %	October Difference[a]
1	58	57	-1	57	-1	48	-10
6 & 7	76	79	+3	88	+12	44	-32
8 & 9	77	73	-4	48	-29	71	-6
12	100	100	0	100	0	94	-6
19	87	87	0	85	-2	86	-1
20	54	74	+20	55	+1	22	-32
21	83	NO ADDITIONAL DATA					
32	86	85	-1	75	-11	75	-23
34	100	96	-4	70	-30	64	-36
36	48	47	-1	38	-10	45	-3
40 & 41	77	78	+1	81	+4	63	-14
43,45,46,47, & 48	97	95	-2	84	-13	83	-14
52,53,&55	100	100	0	100	0	100	0
MEAN	80.2	80.9	+0.7	73.4	- 6.8	66.3	-13.9

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1 & 3	91	90	-1	84	-7	65	-26
13	100	100	0	100	0	83	-17
14	58	59	+1	64	+6	61	+3
25,26,&27	85	86	+1	90	+5	79	-6
MEAN	83.5	83.8	+0.3	84.5	+1	72	-11.5

[a] Difference from the June-August percentage.

Appendix 10. Distribution of elk observations among winter (January-March) use areas used by elk that originated from a given summer (June-August) use area. Observations are presented as percentages of all winter observations with the number of the observations presented in parentheses.

Summer Use Area	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Total No. Locations
1	2	52 (14)	1	26 (7)	3	19 (5)	5	3 (1)					27
6	4	76 (28)	3	24 (9)									37
7	4	100 (12)											12
6 & 7	4	82 (40)	3	18 (9)									49
8	5	58 (34)	3	20 (12)	2	12 (7)	1	10 (6)					59
9	5	55 (16)	4	45 (13)									29
8 & 9	5	57 (50)	4	15 (13)	3	13 (12)	2	8 (7)	1	7 (6)			88
12	10	89 (32)	12	11 (4)									36
19	16	55 (75)	15	19 (26)	19	17 (23)	21	2 (3)	23	2 (3)	14	1 (2)	
	18	1 (2)	22	1 (1)	26	1 (1)	36	1 (1)					137
20	17	36 (43)	22	19 22)	23	16 (19)	16	10 (12)	36	5 (6)	18	4 (5)	
	20	3 (4)	19	2 (2)	26	2 (2)	29	2 (2)	21	1 (1)			118
21	18	58 (11)	17	21 (4)	21	21 (4)							19
25	27	48 (27)	24	33 (19)	25	12 (7)	26	5 (3)	17	2 (1)			57
29	28	37 (7)	22	26 (5)	29	21 (4)	36	16 (3)					19
30	28	100 (5)											5
29 & 30	28	50 (12)	22	21 (5)	29	16 (4)	36	13 (3)					24
32	31	65 (15)	18	17 (4)	17	9 (2)	32	9 (2)					23
34	33	85 (41)	34	15 (7)									48
36	16	45 (29)	22	17 (11)	17	14 (9)	36	9 (6)	19	8 (5)	29	3 (2)	
	14	2 (1)	20	2 (1)									64
40	39	80 (8)	37	10 (1)	38	10 (1)							10
41	37	35 (11)	42	31 (10)	39	25 (8)	38	9 (3)					32
40 & 41	39	38 (16)	37	29 (12)	42	24 (10)	38	9 (4)					42
43	42	78 (42)	44	5 (3)	51	5 (3)	48	4 (2)	49	4 (2)	58	4 (2)	54
45	42	67 (6)	44	33 (3)									9
46	51	29 (8)	59	26 (7)	42	22 (6)	44	11 (3)	48	4 (1)	49	4 (1)	
	58	4 (1)											27
47	51	56 (5)	59	22 (2)	48	11 (1)	58	11 (1)					9
48	51	30 (8)	60	30 (8)	48	12 (3)	58	12 (3)	49	8 (2)	59	8 (2)	26
43,45, 46,47,48	42	43 (54)	51	19 (24)	59	9 (11)	44	7 (9)	48	6 (7)	58	6 (7)	
	60	6 (8)	49	4 (5)									125
40,41,43, 45,46,47,48	42	38 (64)	51	15 (24)	39	10 (6)	37	7 (12)	59	7 (11)	44	5 (9)	
	60	5 (8)	48	4 (7)	58	4 (7)	49	3 (5)	38	2 (4)			167
52	52	50 (6)	54	50 (6)									12
53	57	29 (7)	52	25 (6)	54	25 (6)	56	21 (5)					24
55	57	58 (7)	56	42 (5)									12
52,53,55	57	29 (14)	52	25 (12)	54	25 (12)	56	21 (10)					48

Appendix 11. Distribution of elk observations among summer (June-August) use areas used by elk that originated from a given winter (January-March) use area. Observations are presented as percentages of all summer observations, with the number of observations presented in parentheses.

Winter Use Area	Area	% (No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Total No. Locations
2	3	50 (24)	1	46 (22)	2	4 (2)							48
4	6	40 (16)	9	32 (13)	7	28 (11)							40
5	8	60 (40)	1	32 (21)	3	4 (3)	9	4 (3)					67
10	12	100 (55)											55
11	13	57 (13)	12	43 (10)									23
15	19	87 (27)	15	13 (4)									31
16	19	67 (187)	20	16 (45)	36	12 (33)	16	3 (7)	22	2 (5)	15	1 (1)	278
17	20	53 (66)	19	14 (18)	21	9 (11)	24	8 (10)	25	7 (9)	22	6 (8)	
	27	2 (2)	32	1 (1)									125
18	21	37 (15)	20	30 (12)	32	28 (11)	19	3 (1)	31	3 (1)			40
17&18	20	47 (78)	21	16 (26)	19	12 (19)	32	7 (12)	24	6 (10)	22	5 (8)	
	25	5 (9)	27	1 (2)	31	1 (1)							165
22	36	45 (45)	20	40 (40)	22	9 (9)	19	3 (3)	23	3 (3)			100
23	19	23 (15)	24	18 (12)	26	17 (11)	21	14 (9)	27	11 (7)	25	8 (5)	
	23	8 (6)	16	1 (1)									66
28	29	64 (9)	30	36 (5)									14
31	32	96 (24)	31	4 (1)									25
33	34	95 (55)	33	5 (3)									58
37	41	96 (22)	40	4 (1)									23
38	41	96 (22)	40	4 (1)									23
39	41	90 (9)	40	10 (1)									10
42	43	72 (34)	45	15 (7)	41	9 (4)	46	4 (2)					47
44	45	78 (7)	46	22 (2)									9
37,38,39	41	95 (53)	40	5 (3)									56
42 & 44	43	61 (34)	45	25 (14)	41	7 (4)	46	7 (4)					56
37,38,39, 42 & 44	41	51 (57)	43	30 (34)	45	12 (14)	40	3 (3)	46	4 (4)			112
54	52	93 (13)	53	7 (1)									14
56	53	50 (4)	55	50 (4)									8
57	53	50 (4)	55	50 (4)									8
56 & 57	53	50 (8)	55	50 (8)									16
54,56,57	52	43 (13)	53	30 (9)	55	27 (8)							30
51	48	36 (14)	46	28 (11)	47	23 (9)	49	8 (3)	43	3 (2)			39
58	46	35 (11)	47	28 (9)	48	28 (9)	43	6 (2)	49	3 (1)			32
59	46	52 (11)	47	43 (9)	49	5 (1)							21
58 & 59	46	41 (22)	47	34 (18)	48	17 (9)	43	4 (2)	49	4 (2)			53
51,53,59	46	36 (33)	47	29 (27)	48	25 (23)	49	6 (5)	43	4 (4)			92
60	48	71 (5)	49	29 (2)									7
51,58,59, & 60	46	34 (33)	48	28 (28)	47	27 (27)	49	7 (7)	43	4 (4)			99

Appendix 12. Distribution of elk observations among use areas used by elk that originated from a given all season (January-March and June-August) use area. Observations are presented as percentages of all observations made during the specified time period, with the number of observations presented in parenthesis.

All Season Use Area	Area % (No.)	Area %(No.)	Area %(No.)	Area %(No.)	Area %(No.)	Area %(No.)	Total No. Locations
3	3 63 (104)	1 17 (28)	2 15 (24)	8 5 (8)	5 1 (1)		165
1 & 3	3 54 (122)	1 24 (56)	2 17 (40)	8 4 (8)	5 1 (2)		228
1,2,3	1 27 (85)	2 21 (64)	3 49 (152)	8 2 (8)	5 1 (3)		312
13	13 69 (24)	11 31 (11)					35
14	14 57 (82)	19 23 (34)	16 12 (18)	13 6 (8)	11 2 (3)		145
24	24 83 (72)	25 11 (9)	17 2 (2)	26 2 (2)	27 2 (2)		87
26	26 19 (22)	27 38 (45)	23 37 (43)	25 5 (6)	19 1 (1)		117
27	27 52 (54)	23 17 (17)	25 17 (18)	26 12 (12)	17 1 (1)	19 1 (1)	103
26 & 27	26 15 (34)	27 45 (99)	23 27 (60)	25 11 (24)	19 1 (2)	17 1 (1)	220
25,26,27	25 14 (45)	26 12 (37)	27 45 (146)	23 17 (55)	24 11 (34)	17 1 (2)	
	19 1 (2)						321
28,29,30	36 30 (26)	28 27 (24)	29 25 (22)	30 12 (10)	22 6 (5)		88
49	48 23 (17)	46 15 (11)	51 15 (11)	47 12 (9)	60 11 (8)	59 9 (7)	
	49 8 (6)	58 4 (3)	43 3 (2)	47 15 (9)			74
50	48 20 (12)	46 19 (11)	51 19 (11)	59 12 (7)	49 7 (4)	58 5 (3)	
	43 3 (2)						59

Appendix 13. Distribution of elk observations among winter (January-March) use areas used by elk that originated from a given all season (January-March and June-August) use area. Observations are presented as percentages of all winter observations, with the number of observations presented in parentheses.

All Season Use Area	Area % (No.)	Area % (No.)	Area % (No.)	Area % (No.)	Area % (No.)	Area % (No.)	Total No. Locations
3	3 57 (40)	2 32 (22)	1 10 (7)	5 1 (1)			70
1 & 3	3 46 (45)	2 37 (36)	1 15 (14)	5 2 (2)			97
1,2,3	1 16 (21)	2 44 (58)	3 38 (51)	5 2 (3)			133
13	13 50 (11)	11 50 (11)					22
14	14 55 (34)	16 27 (17)	19 7 (4)	13 6 (4)	11 5 (3)		62
24	24 95 (39)	17 5 (2)					41
26	26 15 (11)	23 49 (35)	27 29 (21)	25 7 (5)			72
27	27 47 (27)	23 27 (16)	25 13 (7)	26 13 (7)	17 2 (1)		58
26 & 27	26 14 (18)	27 37 (48)	23 39 (51)	25 9 (12)	17 1 (1)		130
25,26,27	25 9 (17)	26 11 (21)	27 41 (75)	23 28 (51)	24 10 (19)	17 1 (2)	185
28,29,30	28 67 (24)	29 11 (4)	22 14 (5)	36 8 (3)			36
49	51 31 (11)	60 22 (8)	59 20 (7)	48 9 (3)	49 9 (3)	58 9 (3)	35
50	51 41 (11)	59 26 (7)	48 11 (3)	49 11 (3)	58 11 (3)		27

Appendix 14. Distribution of elk observations among summer (June-August) use areas used by elk that originated from a given all season (January-March and June-August) use area. Observations are presented as percentages of all summer observations, with the number of observations presented in parentheses.

All Season Use Area	Area	% (No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Area	%(No.)	Total No. Locations
3	3	67 (64)	1	22 (21)	8	9 (8)	2	2 (2)					95
1 & 3	3	59 (77)	1	32 (42)	8	6 (8)	2	3 (4)					131
1,2,3	1	36 (64)	2	3 (6)	3	56 (101)	8	5 (8)					179
13	13	100 (13)											13
14	14	58 (48)	19	36 (30)	13	5 (4)	16	1 (1)					83
24	24	72 (33)	25	20 (9)	26	4 (2)	27	4 (2)					46
26	26	28 (11)	27	60 (24)	23	8 (3)	25	2 (1)	19	2 (1)			40
27	27	60 (27)	25	25 (11)	26	11 (5)	23	2 (1)	19	2 (1)			45
26 & 27	26	18 (16)	27	57 (51)	25	31 (12)	23	10 (9)	19	2 (2)			90
25,26,27	25	21 (28)	26	12 (16)	27	52 (71)	24	11 (15)	23	3 (4)	19	1 (2)	136
28,29,30	29	35 (18)	30	20 (10)	36	45 (23)							51
49	48	36 (14)	46	28 (11)	47	23 (9)	49	8 (3)	4	3 5(2)			39
50	46	34 (11)	47	28 (9)	43	6 (2)	49	3 (1)					32

Appendix 15. Number of telemetered elk migrating into or out of all summer use areas during each month of the migration period. Data include all season Use Areas 1-3, 13, and 25-62-27.

Migration into			Migration from		
Month	No. of elk	%	Month	No. of elk	%
February	4	7	September	2	4
March	13	25	October	9	18
April	19	36	November	14	28
May	14	26	December	11	22
June	3	6	January	10	20
Total	53	100	February	4	8
			Total	50	100

Appendix 16. Number of telemetered elk migrating into or out of all winter use areas during each month of the migration period. Data include all season Use Area 24.

Migration from			Migration into		
Month	No. of elk	%	Month	No. of elk	%
February	1	3	September	2	6
March	9	25	October	5	14
April	17	47	November	7	19
May	9	25	December	14	39
Total	36	100	January	6	17
			February	2	5
			Total	36	100

Appendix 17. The proportion of each summer use area's subpopulation of elk migrating to or from the summer use area during each month of the migration period.

Summer Use Area	SPRING				FALL			
	Month returned	%	Cum. %	No. of elk	Month left	%	Cum. %	No .of elk
6 - 7	April	75	75		Oct.	71	71	
	May	13	88		Nov.	29	100	7
	June	12	100	8				
8 - 9	March	14	14		Sept.	13	13	
	April	79	93		Oct.	19	32	
	May	7	100	14	Nov.	68	100	16
12	March	80	80		Nov.	50	50	
	April	20	100	5	Dec.	50	100	5
19	February	4	4		Oct.	13	13	
	March	39	43		Nov.	18	31	
	April	41	84		Dec.	30	61	
	May	12	96		Jan.	35	96	
	Non-Migrant	4	100	24	Non-Migrant	4	100	23
20	February	7	7		Oct.	13	13	
	March	20	27		Nov.	34	47	
	April	60	87		Dec.	40	87	
	May	13	100	15	Jan.	13	100	15
21	February	25	25		Nov.	25	25	
	March	50	75		Dec.	75	100	4
	April	25	100	4				
32	March	33	33		Dec.	50	50	
	April	33	66		Jan.	50	100	4
	May	33	99	3				
34	March	33	33		Sept.	33	33	
	April	67	100	6	Nov.	67	100	6
36	March	45	45		Oct.	13	13	
	April	33	78		Nov.	50	63	
	May	11	89		Dec.	37	100	8
	June	11	100	9				
40,41,43,45, 46,47,48	March	8	8		Oct.	8	8	
	April	42	50		Nov.	17	25	
	May	50	100	12	Dec.	17	42	
					Jan.	50	92	
					Feb.	8	100	12
52,53,55	February	25	25		Nov.	50	50	
	March	25	50		Jan.	25	75	
	April	50	100	4	[a]	25	100	4

[a] Joint use of summer and winter range all winter.

Appendix 18. The proportion of each winter use area's subpopulation of elk migrating to or from that area during each month of the migration period.

Summer Use Area	SPRING				FALL			
	Month left	%	Cum. %	No. of elk	Month returned	%	Cum. %	No .of elk
2	March	60	60		Oct.	50	50	
	April	40	100	5	Nov.	25	75	
					Feb.	25	100	4
4	April	60	60		Oct.	60	60	
	May	40	100	5	Nov.	40	100	5
5	March	15	15		Sept.	11	11	
	April	71	86		Oct.	22	33	
	May	14	100	7	Nov.	56	89	
					Dec.	11	100	9
10	March	80	80		Nov.	40	40	
	April	20	100	5	Dec.	60	100	5
11	March	75	75		Dec.	100	100	4
	April	25	100	4				
15	March	40	40		Dec.	80	80	
	April	40	80		Jan	20	100	5
	May	20	100	5				
16	March	42	42		Sept.	9	9	
	April	50	92		Oct.	14	23	
	May	4	96		Nov.	41	64	
	Non-Migrant	4	100	24	Dec.	23	87	
					Jan	8	95	
					Non-Migrant	5	100	22
17 - 18	Feb.	5	5		Sept.	17	17	
	March	29	34		Oct.	5	22	
	April	61	95		Nov.	39	61	
	May	5	100	18	Dec.	17	78	
					Jan.	22	100	18
22	March	30	30		Oct.	10	10	
	April	20	50		Nov.	40	50	
	May	30	80		Dec.	40	90	
	June	10	90		Non-Migrant	10	100	10
	Non-Migrant	10	100	10				
23	March	50	50		Nov.	10	10	
	April	40	90		Dec.	80	90	
	Non-Migrant	10	100	10	Non-Migrant	10	100	10
31	March	33	33		Dec.	100	100	3
	April	67	100	3				
33	March	50	50		Sept.	17	17	
	April	50	100	6	Nov.	83	100	6

Appendix 18. (cont.)

Summer Use Area	SPRING				FALL			
	Month left	%	Cum. %	No. of elk	Month returned	%	Cum. %	No .of elk
37,38,39, 42,44	April	56	56		Oct.	11	11	
	May	44	100	9	Nov.	11	22	
					Dec.	56	78	
					Jan.	22	100	9
54,56,57	Feb.	25	25		Nov.	25	25	
	March	25	50		Dec.	50	75	
	April	50	100	4	a	25	100	4
51,58,59, & 60	March	25	25		Dec.	25	25	
	April	50	75		Jan.	25	50	
	May	25	100	4	Feb.	25	75	
					a	25	100	4

[a] Joint use of summer and winter range all winter.

Appendix 19. The proportion of each all season use area's subpopulation of elk migrating to or from that area during each month of the migration period.

Summer Use Area	SPRING				FALL			
	Month returned	%	Cum. %	No. of elk	Month left	%	Cum. %	No .of elk
1 - 3	March[b]	22	22		Oct.[a]	33	33	
	April[b]	22	44		Nov.[a]	11	44	
	May[b]	11	55		Dec.[a]	11	55	
	Non-Migrant	45	100	9	Non-Migrant	45	100	9
13	March[b]	75	75		Dec.[a]	100	100	4
	April[b]	25	100	4				
14	March[b]	25	25		Non-Migrant	100	100	5
	April[c]	13	38					
	Non-Migrant	62	100	8				
24	March[a]	20	20		Dec.[b]	25	25	
	April[a]	20	40		Non-Migrant	75	100	4
	Non-Migrant	60	100	5				
25,26,27	March[b]	19	19		Aug.[a]	6	6	
	April[b]	29	48		Oct.[a]	12	18	
	June[b]	5	53		Dec.[a]	35	53	
	Non-Migrant	47	100	21	Non-Migrant	47	100	17
28,29,30	Feb.[a]	33	33		Jan.[b]	33	33	
	Non-Migrant	67	100	3	Non-Migrant	67	100	3
49 & 50	April[d]	50	50		Oct.[e]	50	50	
	May[a]	50	100	4	Dec.[a]	50	100	4

[a] Left.
[b] Returned.
[c] Entered and left.
[d] Returned for joint use with summer range (April-November)
[e] Returned for joint use with winter range (October-April).

Appendix 20. The percentage of a given use area's subpopulation that occupied both winter and summer ranges during each month of migration. Each time frame listed refers to a distinct group of elk that used both seasonal ranges for that time frame only. Individual elk were not placed into more than one time frame; thus, percentages are additive for each use area.

Use Area	MIGRATION INTO		MIGRATION FROM	
	Month(s)	% elk	Month(s)	% elk
1 -3	Feb	11	Nov. - Dec.	11
	Feb. - April	11	——	0
	March	11	——	0
2	Nov. - Dec.	20	Feb.	20
	——	0	Feb. - April	20
	——	0	March	20
4	——	0	April - May	20
6 - 7	April - May	12	Sept. - Oct.	14
5	Sept. - Nov.	11	——	0
8 - 9	——	0	Sept. - Oct.	13
10	Nov. - Dec.	40	——	0
12	——	0	Nov. - Dec.	40
11	Oct. - Dec.	67	Feb. - March	50
	Nov. - Dec.	33	——	0
13	Jan. - March	25	Oct. - Dec.	50
	Feb. - March	50	Nov. - Dec.	25
14	——	0	——	0
15	Oct. - Dec.	40	Jan. - March	40
	——	0	March - April	20
	——	0	April - May	20
16	July - Sept.	5	Jan. - March	8
	Nov. - Dec.	22	March	13
	Dec.	18	——	0
17 - 18	Sept. - Nov.	17	March - April	27
	Oct. - Dec.	17	——	0
	Dec. - Jan.	5	——	0
19	Jan. - May	4	Oct. - Jan.	4
	Feb. - April	4	Nov. - Dec.	4
	March - April	17	Dec.	30
	——	0	Jan.	4
20	Feb.	7	Aug. - Nov.	12
	March - April	33	Sept. - Oct.	6
	April - May	7	Sept. - Nov.	12
	——	0	Oct. - Nov.	12
	——	0	Oct. - Dec.	12
21	——	0	——	0
22	Aug. - Nov.	10	Feb. - March	10
	Nov. - Dec.	10	March - April	10
	——	0	April - May	20
23	Oct. - Dec.	10	Feb. - March	40
	——	0	March - April	20
24	Oct. - Dec.	25	——	0

Appendix 20. (cont.)

Use Area	MIGRATION INTO		MIRGRATION FROM	
	Month(s)	% elk	Month(s)	% elk
25,26,27	Feb. - March	10	Oct. - Dec.	24
	March - April	15	——	0
28,20,30	——	0	——	0
31	Oct. - Dec.	100	——	0
32	——	0	Aug. - Dec.	25
33	Aug. - Sept.	17	Feb.- March	50
	Oct. - Nov.	17	——	0
34	——	0	Aug. - Sept.	17
	——	0	Oct. - Nov.	17
36	March - April	11	Nov.	13
37,38,39, 42, & 44	Oct. - Nov.	22	——	0
	Nov.	22	——	0
	Nov. - Dec.	33	——	0
40,41,43, 45,46,47, & 48	Feb. - March	8	Oct.	8
	——	0	Nov.	17
	——	0	Nov. - Dec.	50
	——	0	Dec. - Jan.	8
49 & 50	April - Nov.	50	——	0
	Oct. - April	50	——	0
51,58,59, & 60	Oct. - Jan.	25	Jan - March	25
	Nov.	25	——	0
	Nov. - Dec.	25	——	0
	Dec. - March	25	——	0
52,53,55	——	0	Oct. - Nov.	50
	——	0	Nov. - Jan.	25
54,56&57	Nov. - Jan.	33	——	0

Appendix 21. Mean elevation (meters) of elk locations observed within a given use area throughout the entire study and their standard deviations.

Use Area	$\bar{X}$[a]	SD	$\bar{X} \pm$ SD
1	2111.87	163.96	1947.9 - 2275.8
2	2116.38	75.43	2041.0 - 2191.8
3	2132.00	73.72	2058.3 - 2205.7
4	2065.83	79.61	1986.2 - 2145.4
5	2135.09	136.07	1999.0 - 2271.2
6	2380.75	89.29	2191.5 - 2570.0
7	2307.42	58.38	2249.0 - 2365.8
8	2686.73	165.09	2521.6 - 2851.8
9	2377.12	71.60	2305.5 - 2448.7
10	2037.54	88.91	1948.6 - 2126.5
11	2004.97	48.71	1956.3 - 2053.7
12	2135.92	56.12	2079.8 - 2192.0
13	2196.62	43.72	2152.9 - 2240.3
14	2154.57	59.41	2095.2 - 2214.0
15	1889.16	124.30	1764.9 - 2013.5
16	1974.86	98.44	1876.4 - 2073.3
17	1888.57	97.01	1791.6 - 1985.6
18	1985.37	98.09	1887.3 - 2083.5
19	2134.81	258.39	1876.4 - 2393.2
20	2225.63	85.21	2140.4 - 2310.8
21	2064.43	21.08	2043.4 - 2085.5
22	2177.04	73.41	2103.6 - 2250.5
23	2046.20	62.56	1983.6 - 2108.8
24	1989.39	49.98	1939.4 - 2039.4
25	2043.76	36.87	2006.9 - 2080.6
26	2158.22	65.67	2092.6 - 2223.9
27	2220.80	78.78	2142.0 - 2299.6
28	1770.60	420.23	1350.4 - 2190.8
29	1891.48	35.24	1856.2 - 1926.72
30	1692.50	27.90	1664.6 - 1720.4
31	1899.94	199.39	1700.6 - 2099.3
32	2226.94	79.31	2147.6 - 2306.3
33	1983.91	117.45	1866.5 - 2101.4
34	2286.80	34.71	2252.1 - 2321.5
36	2258.60	59.96	2198.6 - 2318.6
37	2111.00	49.62	2061.4 - 2160.6
38	2314.46	81.41	2233.1 - 2395.4
39	2240.42	23.60	2216.8 - 2264.0
40	2478.33	36.32	2442.0 - 2514.7
41	2557.58	90.07	2467.5 - 2647.7
42	2465.96	71.42	2394.5 - 2537.38
43	2829.84	98.62	2731.2 - 2928.5
44	2623.17	159.15	2464.0 - 2782.3
45	2820.00	21.39	2798.6 - 2841.4
46	2756.09	67.69	2688.4 - 2823.8

[a] meters

Appendix 21. (cont.)

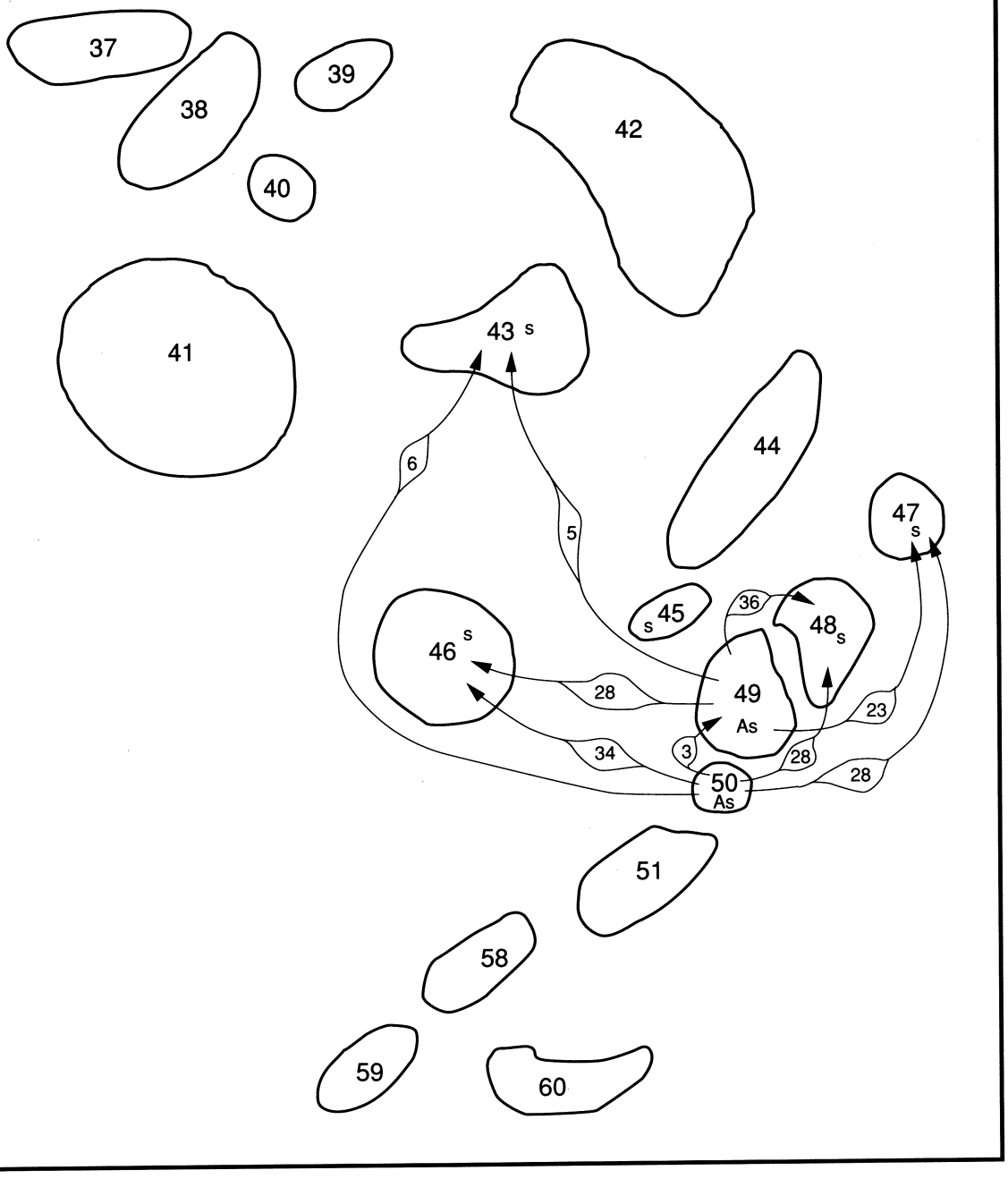
Use Area	$\overline{X}$[a]	SD	$\overline{X} \pm$ SD
47	2745.40	47.69	2697.7 - 2793.1
48	2604.49	94.89	2509.6 - 2699.4
49	2440.21	90.14	2350.1 - 2530.35
50	2382.75	15.84	2366.9 - 2398.6
51	2308.79	49.43	2259.4 - 2358.2
52	2528.59	112.40	2416.2 - 2641.0
53	2421.77	68.97	2352.8 - 2490.7
54	2353.00	135.82	2217.2 - 2488.8
55	2720.25	94.14	2626.1 - 2814.4

[a] meters

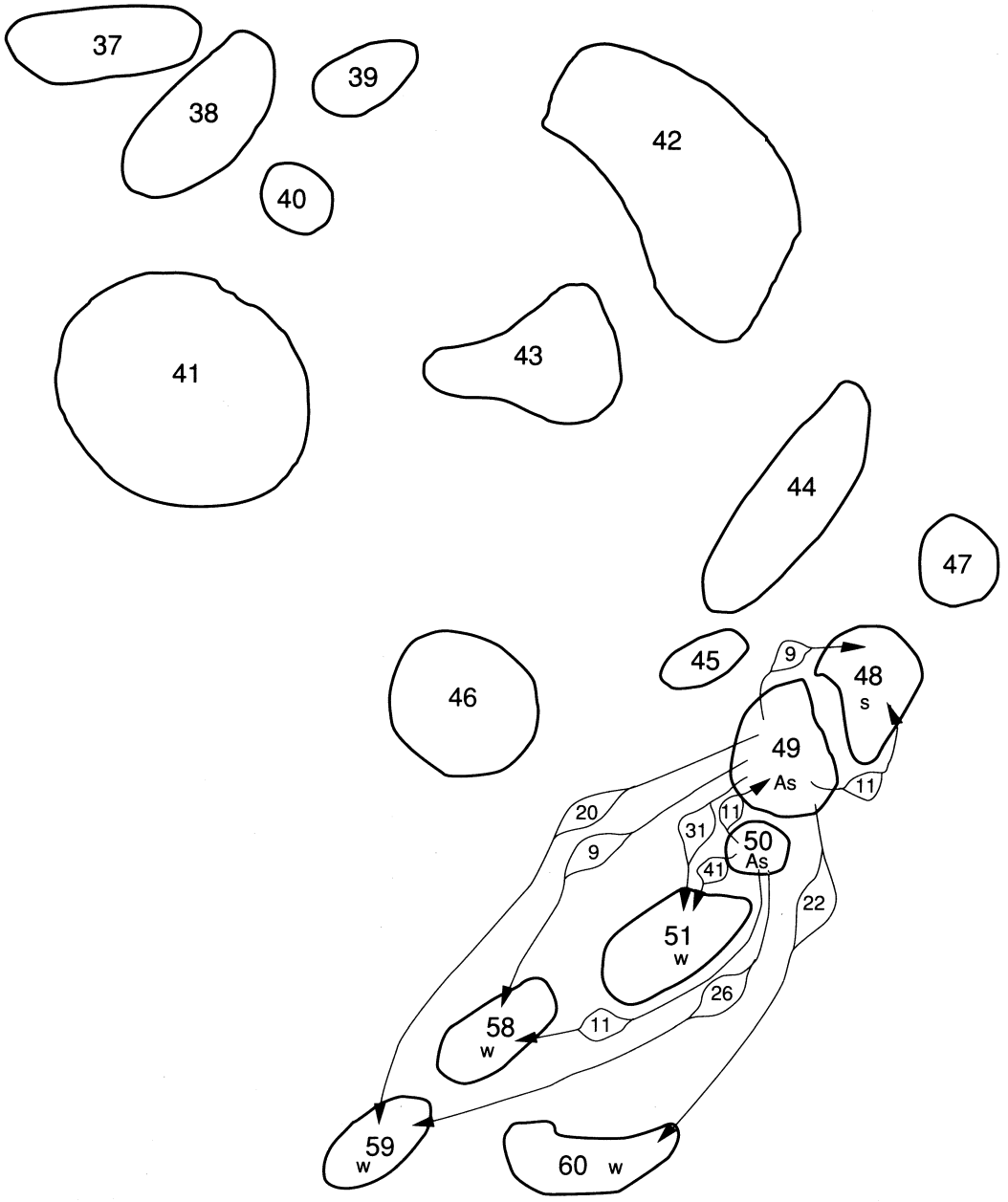
MIGRATION MAPS

The following section presents a series of detailed maps that indicate the degree of seasonal movement between use areas. Values within the arrows indicate the percent of elk movements from a given area to another.

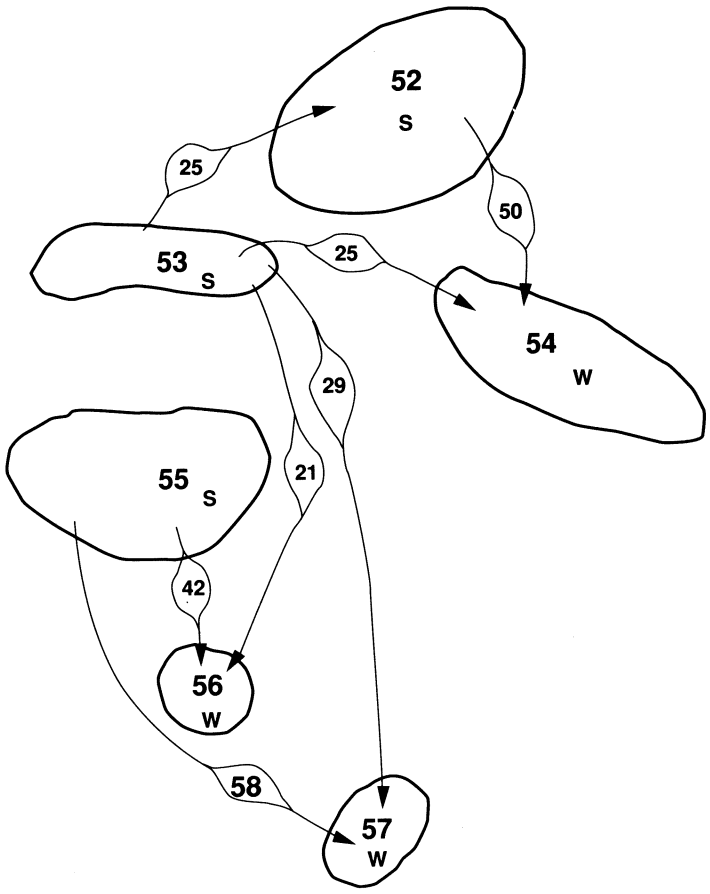
Spring Migration to Summer Use Areas
Source Appendix 14
(from areas 49 & 50 only)



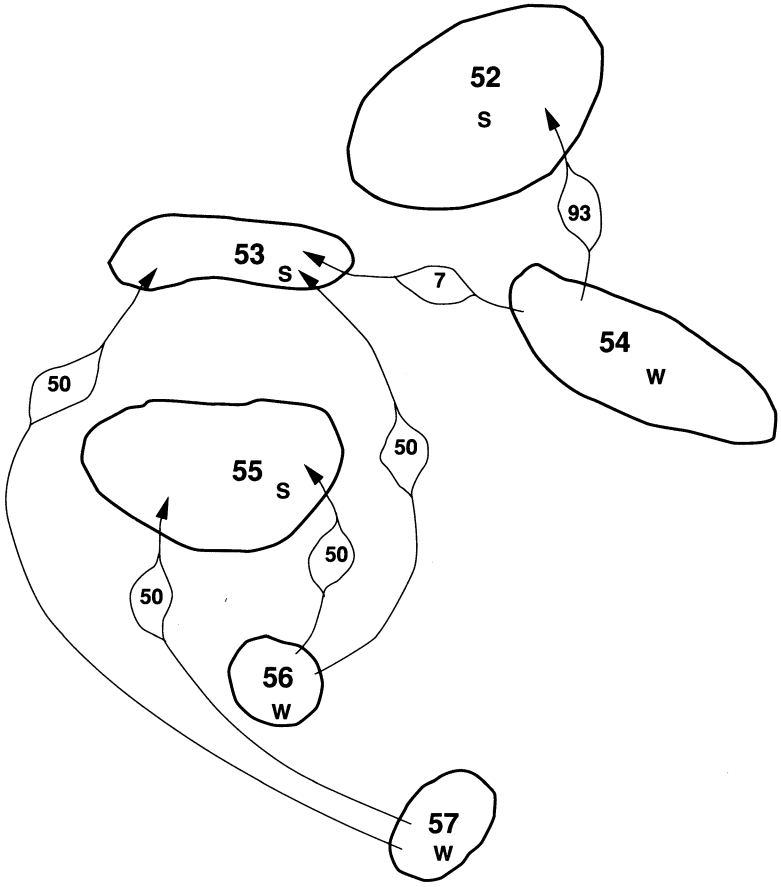
Fall Migration to Winter Use Areas
Source Appendix 13
(from areas 49 & 50 only)



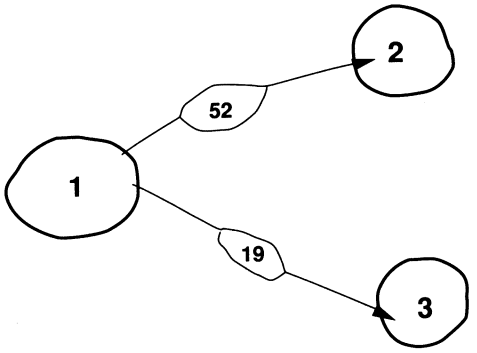
Fall Migration to Winter Use Areas
Source Appendix 10



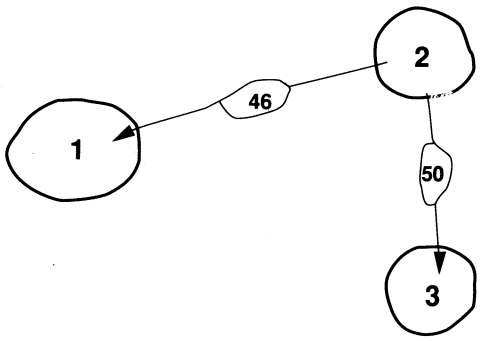
Spring Migration to Summer Use Areas
Source Appendix 11



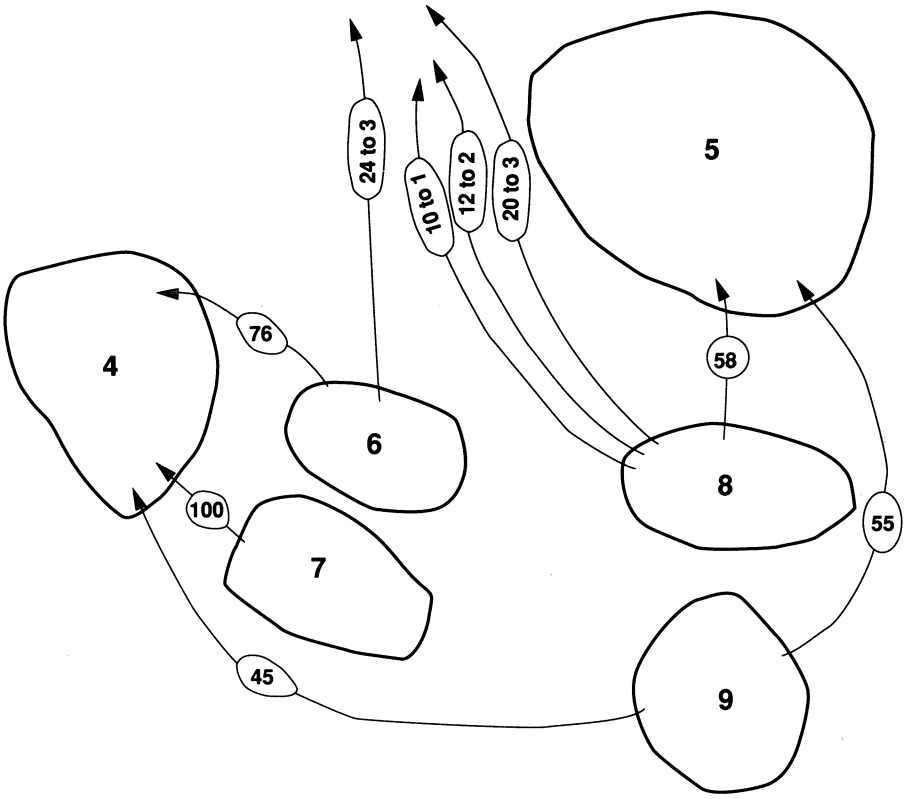
Fall Migration to Winter Use Areas
Source Appendix 10



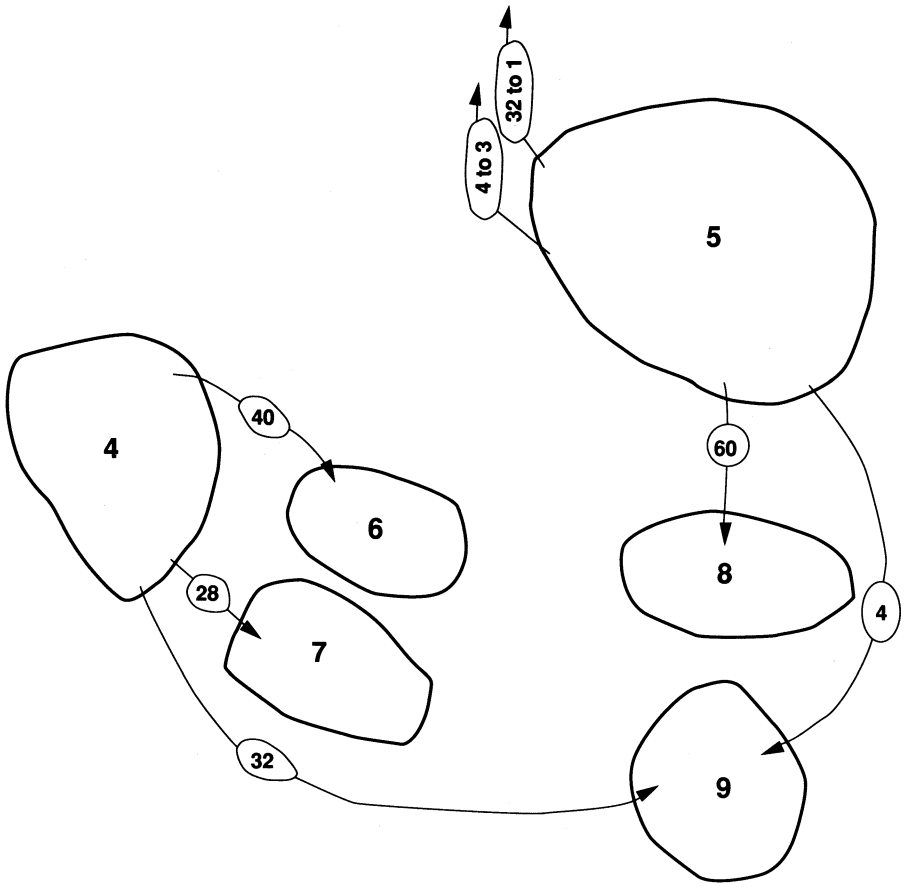
Spring Migration to Summer Use Areas
Source Appendix 11



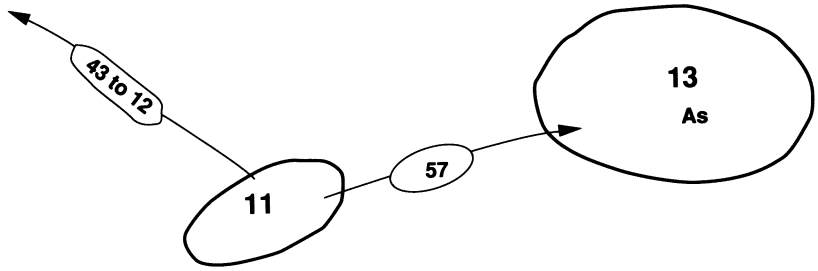
Fall Migration to Winter Use Areas
Source Appendix 10



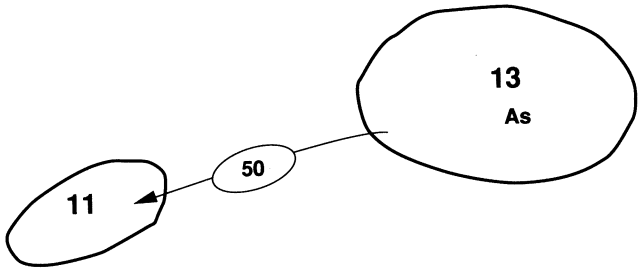
Spring Migration to Summer Use Areas
Source Appendix 11



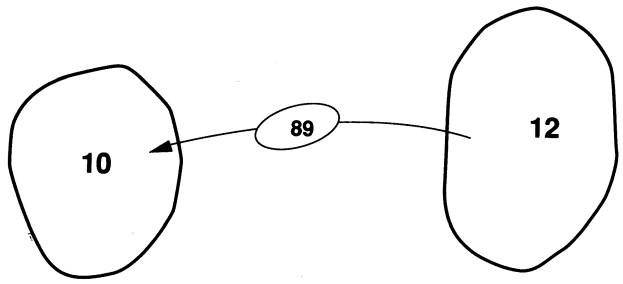
Fall Migration to Winter Use Areas
Source Appendix 10



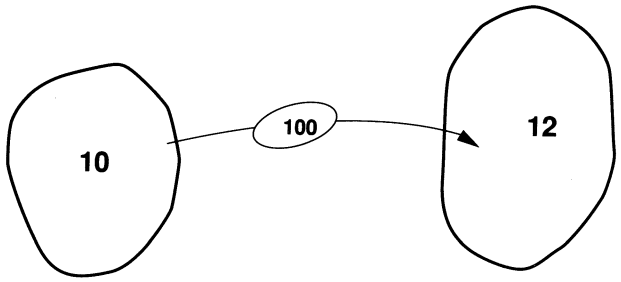
Spring Migration to Summer Use Areas
Source Appendix 13



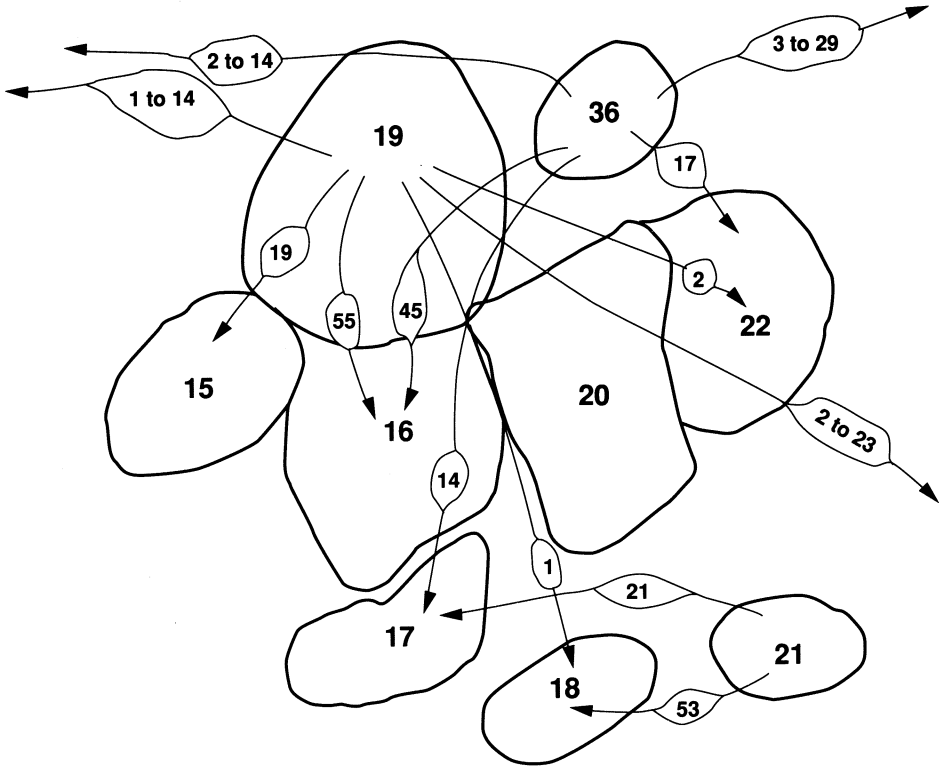
Fall Migration to Winter Use Areas
Source Appendix 10



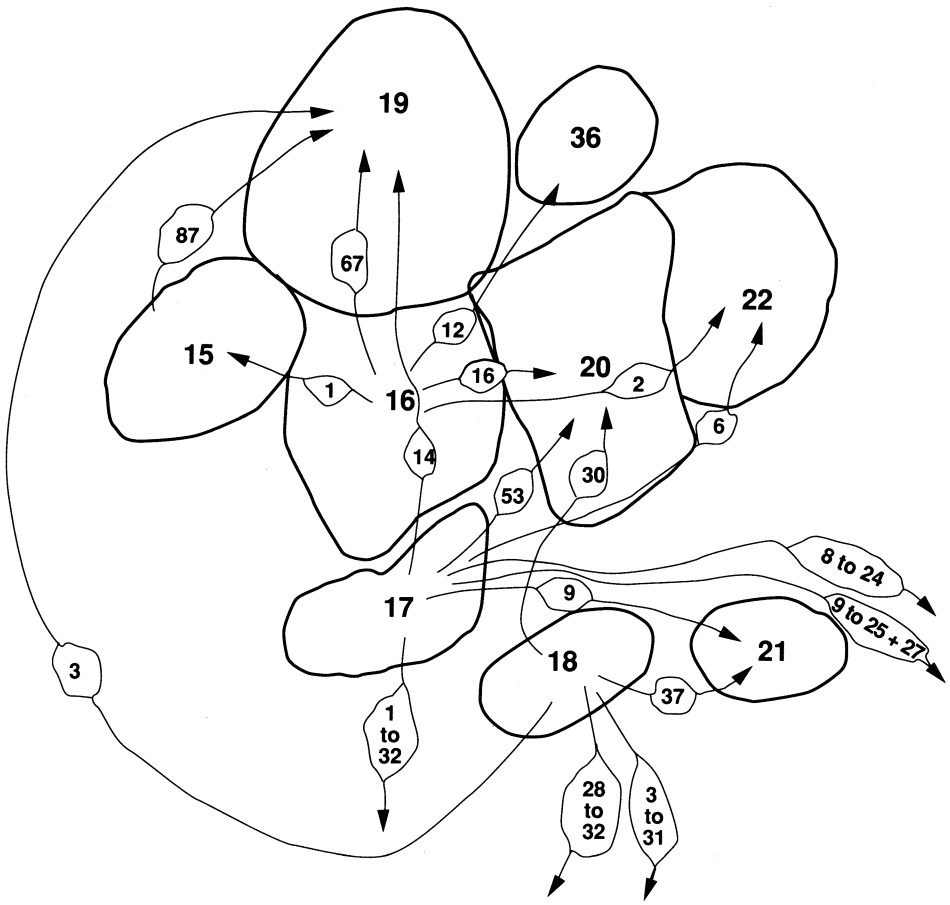
Spring Migration to Summer Use Areas
Source Appendix 11



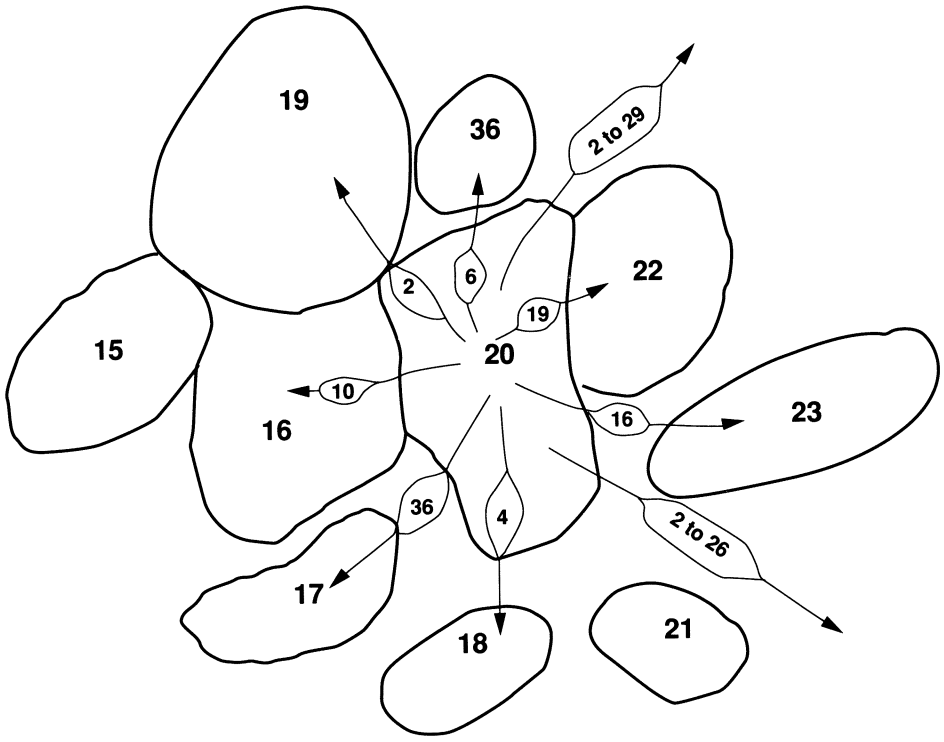
Fall Migration to Winter Use Areas
Source Appendix 10



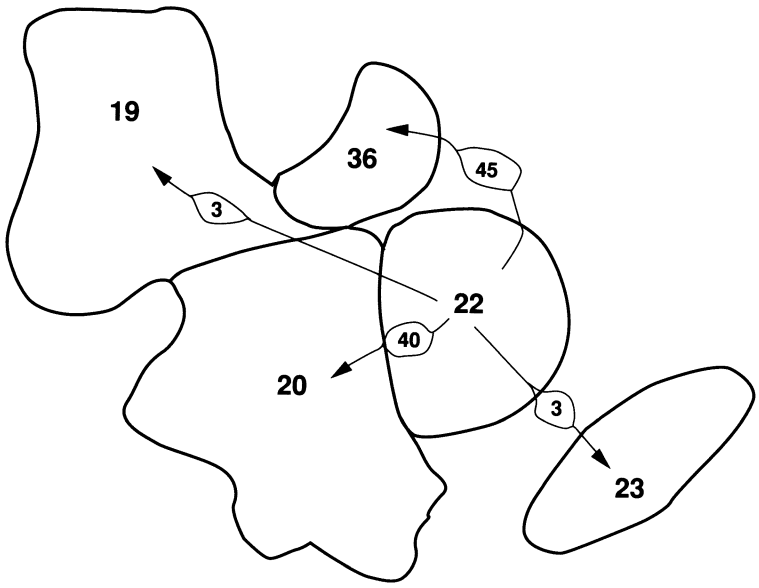
Spring Migration to Summer Use Areas
Source Appendix 11



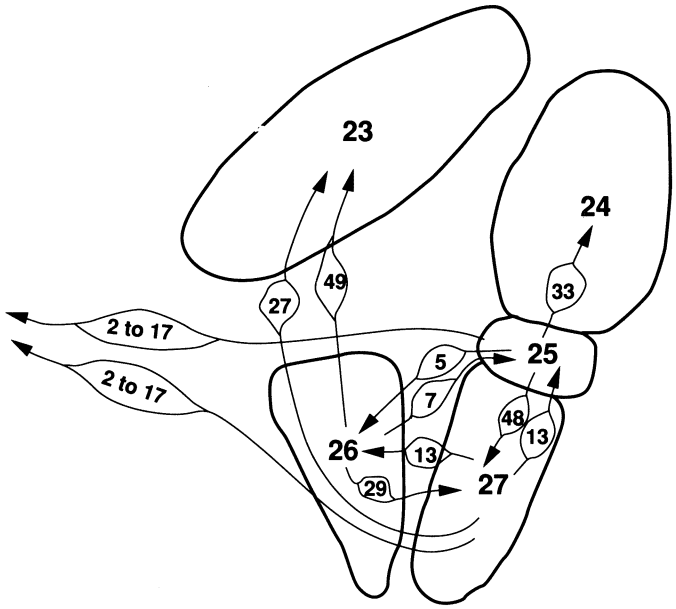
Fall Migration to Winter Use Areas
Source Appendix 10



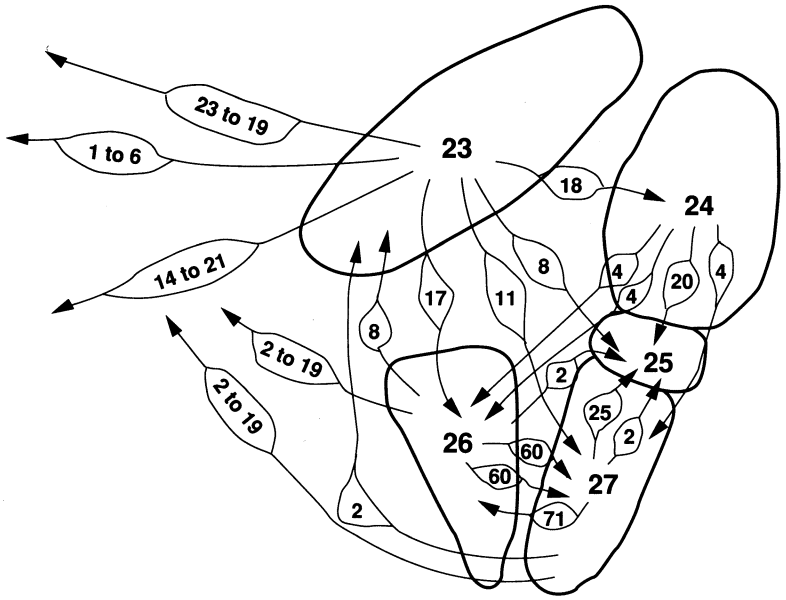
Spring Migration to Summer Use Areas
Source Appendix 11



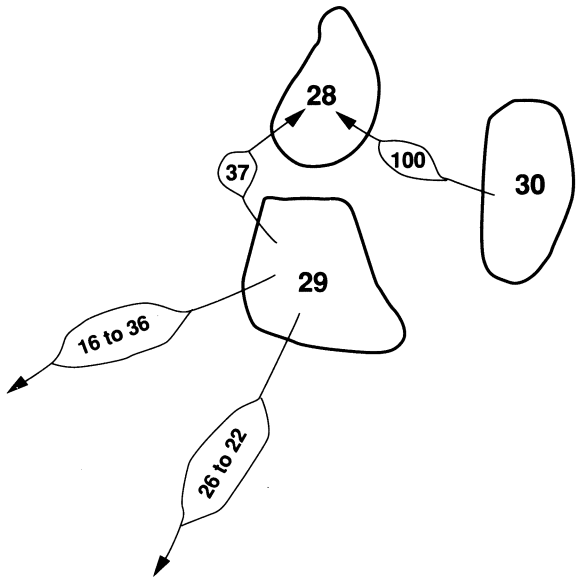
Fall Migration to Winter Use Areas
Source Appendix 10, 13



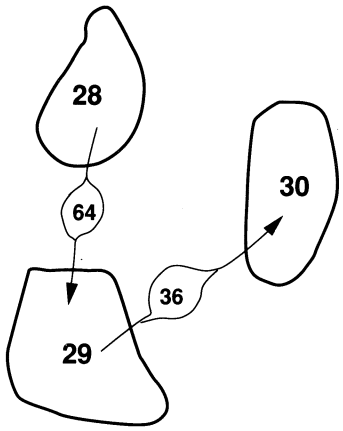
Spring Migration to Summer Use Areas
Source Appendix 11, 14



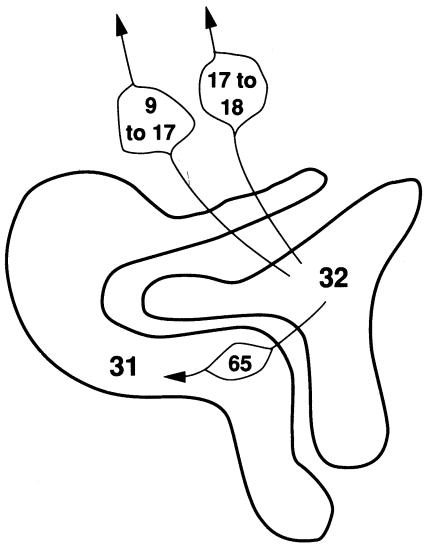
Fall Migration to Winter Use Areas
Source Appendix 10

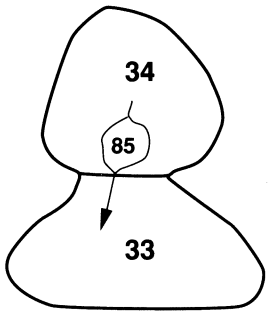


Spring Migration to Summer Use Areas
Source Appendix 11

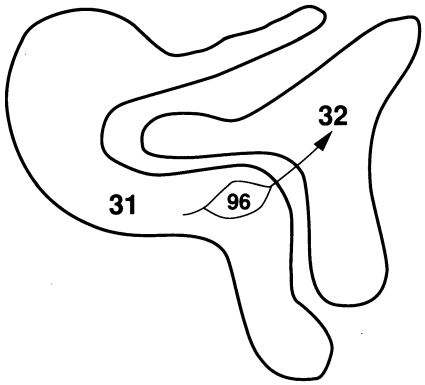


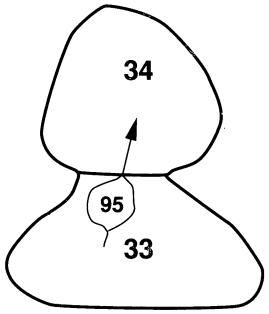
Fall Migration to Winter Use Areas
Source Appendix 10





Spring Migration to Summer Use Areas
Source Appendix 11





NOTES

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Brown, R. L., **Elk seasonal ranges and migrations.**
Arizona Game and Fish Dept., Tech. Rpt. No. 1. 67pp.

From 1985 to 1989, 105 (3 male, 102 female) Arizona elk were radio tracked from aircraft at approximately 30-day intervals. Mapped locations tended to form discrete clusters that identified seasonal use areas. The telemetered elk showed a high degree of fidelity to these seasonal use areas. Subsequently, a population of elk that used each use area was defined, and the level of exchange with other use areas was determined. Thus, migration patterns between use areas and, consequently, herd boundaries were determined. Time and duration of migration periods were documented also.The implications of managing on a herd unit basis are discussed.

Key Words: elk, *Cervus elaphus*, migration, herd, seasonal use, fidelity.

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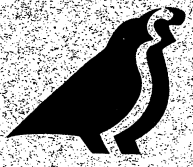

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